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ORIGINAL ARTICLES.

On the West Cumberland Brockram and its Associated Rocks.

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(PLATE XVII.)

Introduction.

FOR many years the breccia of Western Cumberland has been known locally as "The Conglomerate", under which name it figures largely in hundreds of records of borings put down in search of haematite or coal. Since, however, its components consist in general of angular and subangular rather than rounded fragments, the term "conglomerate" is misleading; hence the deposit is here referred to as "Brockram" (broken rock), a descriptive lithological term applied to rocks of similar origin in the Vale of Eden and of definite significance to British geologists.

In the following pages an attempt is made to describe the range and characters of the Brockram; to show how it is equivalent in time to other types of rock in the district, and to discuss the physiographical conditions obtaining in the area during the time of its formation. A series of beds that bear some resemblance to the Hilton Plant Beds is described for the first time.

References to some of the publications of previous workers are given in the sequel.

General Distribution and Thickness.

In general distribution the West Cumberland Brockram originally extended from Brayton, 10 miles beyond Cockermouth, in the north to Millom in the south. In the above area it comes to outcrop between the latitudes of Distington and Gosforth, being exceptionally well exposed in the area between Arlecdon and Egremont. Underground, its best developments are in the Hale–Calder Bridge district and near Kirksanton, Millom (Fig. 1).

The Brockram appears to have once formed a belt extending to an average width of 5 to 6 miles from the present Fell country, thickest perhaps along a zone rather to the east of the central line of the belt, and thinning off in a westerly direction. Eastward also, it must have extended over a strip of the present Fells. Thus,

originally the deposit may have covered an area of at least 5 by 48, or 240 square miles, between Brayton and the Duddon Estuary. This estimate does not allow for the denuded fringe on the Fell country or for a further development along the northern margin of the Lake District, east of Brayton.

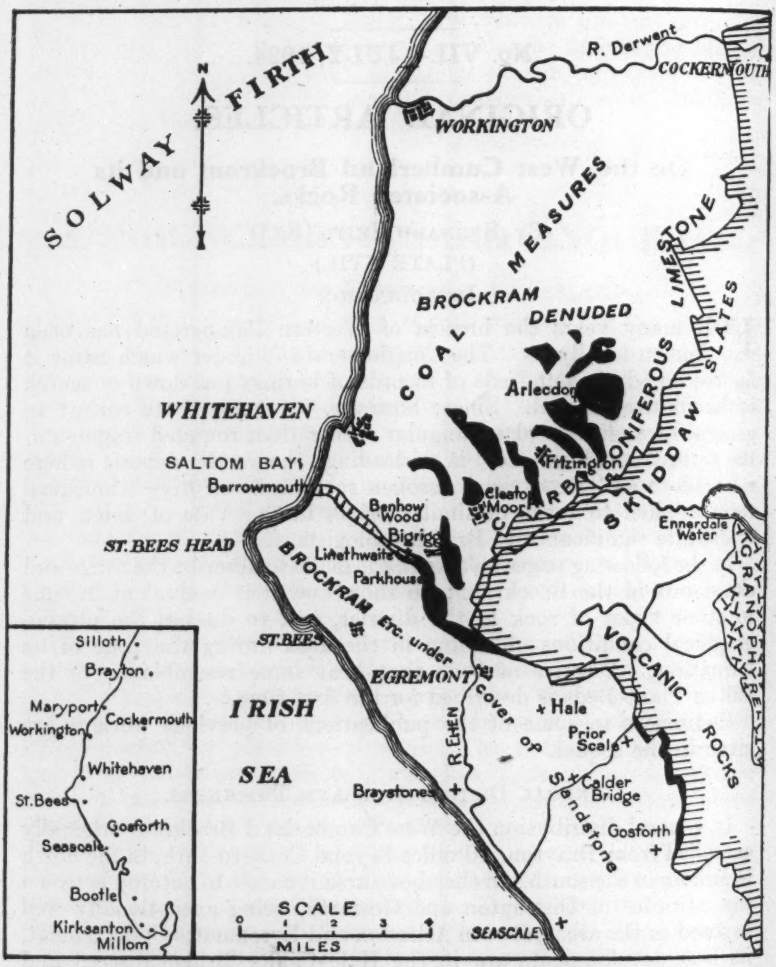


FIG. 1.—Index map showing present distribution of the Brockram (black).

At its thinnest, in a boring at Blue Dial, north of Maryport, it is 3 inches only; at Barrowmouth, St. Bees Head, it varies from 8 inches to 6 feet; whilst at Winder, 5½ miles farther east, where its top is denuded, it must have reached at least 400 feet.[1] At Egremont

[1] J. D. Kendall, *Iron Ores of Great Britain and Ireland*, 1893, p. 74.

it averaged about 235 feet, and in the Hale–Calder Bridge area it has been proved to slightly over 350 feet. Near Millom its maximum thickness is close on 500 feet (B.H. No. 6 Kirksanton).

The Brockram rests with marked unconformity upon the older rocks. In the north it overlies Lower Coal Measures near Maryport, and Upper Coal Measures at Brayton. Farther south it rests upon the Whitehaven Sandstone Series at Barrowmouth; but when followed inland in the direction of Egremont it passes successively across Productive Coal Measures, Millstone Grit, and Carboniferous Limestone Series down to the Fourth Limestone. Still farther south-east it crosses the lower limestones, the Fifth, Sixth, and Seventh, and reposes directly upon the Borrowdale Volcanic Rocks. A similar transgression from Coal Measures to the Limestone Series occurs between Arlecdon and Bigrigg.

Lateral and Upward Passage into other Rock Formations.

Up to recent times[1] the whole of the Brockram has been considered to be of Permian age, and equivalent to that underlying the Magnesian Limestone, as exposed at Barrowmouth, Saltom Bay, St. Bees Head; whilst the overlying St. Bees Shales (gypsiferous) and St. Bees Sandstone were considered to be of younger or Triassic age. Detailed mapping, however, shows that this conception no longer holds good, the facts, in brief, being as follows: When traced inland from the coast the Brockram thickens and becomes equivalent, by lateral passage, not only to the Magnesian Limestone and its underlying brockram, but also to the whole of the St. Bees Shales and part of the St. Bees Sandstone.

Evidence supporting this statement will now be given:—

(*a*) *Barrowmouth.*—The classic section at Barrowmouth (Plate XVII B), which has been visited by so many observers,[2] is as under:—

		ft.
St. Bees Sandstone	Red laminated sandstones and shales, with occasional pale bands of shale and sandstone. Frequently micaceous	200+
St. Bees Shales	Red shales and blocky marls or mudstones, with occasional sandy magnesian bands or nodules. Massive gypsum towards base, with variegated sandy shales	100
Magnesian Limestone	Thin limestones and flaggy shales . 3 ft. Greyish-blue shales and thin limestones . . . . . 3 ft. Limestone . . . . . 10 ft.	16
Brockram	(See below, p. 296) . . 8 inches to *Unconformity.*	6
Whitehaven Sandstone:	False-bedded, grey, yellow, and purple sandstone.	

[1] "Summary of Progress for 1921" (*Mem. Geol. Surv.*), 1922, pp. 62, 63.

[2] Including Sedgwick, *Geol. Trans.*, Ser. II, vol. iv, p. 395; Binney, *Mem. Lit. and Phil. Soc. Manch.*, vol. xii, p. 51; Murchison and Harkness, "On the Permian Rocks of the North-West of England and their extension into Scotland": *Q.J.G.S.*, vol. xx, 1864, pp. 151, 155.

The upward passage from Brockram to Magnesian Limestone is shown by the inclusion of fragments in the lower foot of the Magnesian Limestone, which in its turn passes up into the gypsiferous shale group by alternations of magnesian sandstones and shales (seen in 1915 by the writer, and earlier by Russell [MSS.]).

The Shales pass upwards, conformably, by increase of sandstone beds, into the St. Bees Sandstone.

Near Barrowmouth Farm the Magnesian Limestone is thicker (at Ladysmith Pit close by it measures 38 ft. 6 in.), and includes a 2 ft. bed of limestone breccia with one band of extraneous fragments of rock,[1] suggesting that a considerable amount of breccia or conglomerate was being deposited simultaneously elsewhere. Again the St. Bees Shales, overlooking the cliff road near this point, contain fine dustings of breccia material that indicate the lateral change that was taking place farther to the east during their deposition.

(*b*) *Ben How and Roskapark Woods.*—On tracing these outcrop rocks inland we find that the Shales appear to thicken, the Magnesian Limestone becomes somewhat thinner, but the Brockram more or less retains its thickness.

At Ben How Wood, about 1 mile south-east of Ladysmith Pit, the following section occurs on the east side of the road : Magnesian Limestone, 12 feet ; Brockram, 10 feet ; resting upon purple-stained shales of the Productive Coal Measures.

From evidence obtained in this neighbourhood the Limestone must be over 20 feet in thickness, possibly near 30. In Roskapark Wood, west of the road, the overlying St. Bees Shales appear as red marls and shales, nodular, hard and blocky in places, with occasional thin greyish magnesian bands.

(*c*) *Bellhouse Gill.*—A little farther south, 16 feet or more of the Limestone is faulted against blue-purplish Coal Measure Shales, the Brockram being cut out. The St. Bees Shales contain sandy bands cemented in many cases by carbonates. Some beds are flaggy and micaceous and some are greenish in colour.[2]

(*d*) *Linethwaite Gill.*—Passing now to the eastern side of the St. Bees–Whitehaven Valley a remarkable change is seen to have occurred. In the lower part of Linethwaite Gill the basement brockram has increased in thickness, the Magnesian Limestone has shrunk to about 2 feet of hard, smooth, close-grained flaggy rock, whilst a breccia or brockram of the same type as that below has developed in the St. Bees Shales and overlies the Limestone. The estimated thickness of the lower brockram, at a point about 200 yards south-east of Linethwaite House, is 30 feet, whilst the upper brockram with its intercalated shales, probably measures a few feet more. Higher up the Gill, towards the south, the combined divisions

[1] "Summary of Progress for 1921" : op. cit., p. 65.

[2] The Limestone was traced as far inland as this point by Murchison and Harkness : op. cit., p. 155.

are faulted against St. Bees Sandstone. The following section from a boring put down west of the Gill, a little north of Parkhouse Farm, shows how the Brockram has expanded still further :—

	ft.	in.
Breccia, with some sandy and shaly beds . . .	97	6
Limestone, red and grey	1	6
Breccia	50	0
On shales and sandstones of the Millstone Grit or Coal Measures.		

Both the upper and lower breccias contain fragments of Carboniferous Limestone.

The thin band of limestone has been detected in a number of borings, and is imperfectly seen in brockram about 120 yards north of Parkhouse Farm. It is of a coarser type than that in the lower part of the Gill (Linethwaite), but may be matched closely with beds in the lower part of the limestone of Bell House Gill and Ben How Wood across the St. Bees–Whitehaven Valley.

Overlying the highest bed of brockram is a considerable thickness of red sandstone, marls, and shales with dustings of breccia material, which in turn pass upwards into the typical St Bees Sandstones with their wayboards of shale.

(*e*) *Wyndham Mines.*—Bore sections farther south (west of Egremont) show a similar lateral passage of shaly, marly, and gypsiferous material into breccias, and the interpolation of a thin bed of limestone in the Brockram, which here rests upon the lower part of the Fourth Limestone of the Carboniferous Limestone Series. The upward passage into gypsiferous marls and shales also is clear.

(*f*) *Egremont–Calder Bridge.*—South-east of Egremont the included bed of limestone can no longer be detected in borings, and the St. Bees Shales begin to disappear. A boring in the Florence–Ullcoats Mines area, for example, shows only about 20 feet of sandy shales separating the St. Bees Sandstone from the Brockram, which is here about 220 feet in thickness. Farther south and east the St. Bees Shales disappear and are no longer recognizable, and the Brockram is followed immediately by sandstone of St. Bees type. More than this, the Brockram includes sandy and shaly beds, in part micaceous, similar to those in the St. Bees Sandstone (but frequently somewhat darker in tint), a fact which seems to show that the deposits have now become the basement beds of the St. Bees Sandstone. Further proof of contemporaneity of the two series is afforded by the occurrence of thin beds of breccia at intervals in the sandstone many feet above the main Brockram. In one case, for example (No. 11, B.H. Hale, Egremont Mining Co.), a band of this material occurs 263 feet above the top of the Brockram proper.

Thus it appears to be clear that breccias were being formed continuously from pre-Magnesian Limestone well into St. Bees Sandstone times.

We may, then, represent the occurrence of the West Cumberland Brockram in the Whitehaven area in the following manner (Fig. 2) :

(*g*) *Kirksanton* (*Millom District*).—In recent years several deep borings[1] for haematite have been made near Kirksanton by the Millom and Askham Iron Co., Ltd.

A section of one of these (Layriggs, or No. 1) was published in 1919,[2] but at that date its full significance was not appreciated.

Examination of the cores of the later bores, and records of older ones, has shown that the New Red Beds are here represented by a red sandstone series resting upon a sequence of basement brockrams and shales unconformable upon older rocks. In some of the borings the brockrams included, or were underlain by, a group of grey beds (see No. 1 B.H.), which was examined carefully, as being a possible index horizon, whereby post-New Red faulting might be detected. The grey beds were found to contain shales with obscure plant remains, and bands of impure magnesian limestone with casts of fossils which possess a distinct Permian appearance, although no

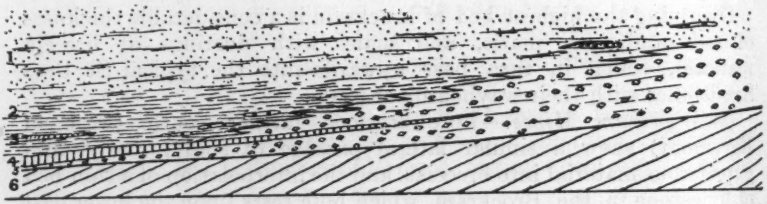


FIG. 2.—Diagrammatic section showing lateral passage of the Brockram into other deposits. 1. St. Bees Sandstone; 2. St. Bees Shales; 3. Gypsum; 4. Magnesian Limestone; 5. Brockram; 6. Carboniferous Rocks.

specific identifications can be made. Underlying these beds there occurred, in places, a honeycombed magnesian limestone, or dolomitic breccias.[3] This series challenges comparison with the Hilton Shales and associated beds in the Vale of Eden;[4] beds which there represent the highest "Permian" and underlie the St. Bees Shales. The following table shows their occurrence in several of the boreholes:—

[1] Permission to publish details has been granted by Mr. J. Graham, of the Millom and Askham Co., Ltd.

[2] "The Haematite Iron Ores of West Cumberland, Lancashire, etc.": op. cit., pp. 17, 18.

[3] The records read:—

B.H. 1. Limestone breccia.
,, 3. Brown and grey limestone, loughy, 6 ft.
,, 5. Grey and brown limestone.
,, 6. Very coarse limestone, with nodules, 8 ft.; coarse yellow limestone, 7 ft. 8 in.; coarse variegated limestone, 13 ft. 2 in.
,, 7. Brown decomposed limestone [angular lumps of limestone as breccia in a yellow magnesian matrix], 30 ft. 2 in.
,, 8. Dark-grey honeycombed limestone, 11 ft. 9 in.; grey honeycombed limestone, 35 ft. 7 in.

[4] Sir Roderick Murchison and Robert Harkness, "On the Permian Rocks of the North-West of England and their extension into Scotland": op. cit., pp. 154, 162.

Borehole.	1	Standing Stones.	75	70	4	72	3	7
Height above O.D.	19	30 ?	20	21	20·6	20	49·6	32·6
Surface Deposits	126·11	116·8	70·5	70·0	94·0	84·8	96·6	108·3
New Red Breccias with shales and marls	99·11	23·4	433·4	343·6	448·6	336·4	246·6	309·9
Grey Beds	*31·4*	*25·11* ?	*35·9* or *67·6*	*58·10*	*78·0*	*70·0*	*60·9*	*45·4*
Magnesian L'stone and Breccias (highly dolomitic) and red marls	91·0	61·6 ?	—	—	—	—	6·0 (? Mag. Limestone)	82·11
Carboniferous Limestone	838·0	282·5+	93·6+ or 61·9+	123·8+	499·6 (? Fault)	253·11+	386·9	—
Basement Beds	31·10+	—	—	—	—	—	127·6+	—
Volcanic Rocks	—	—	—	—	52·0+	—	—	62·6+
Skiddaw Slates	—	—	—	—	—	—	—	—

Borehole.	8	5	6	2	11	9	10
Height above O.D.	65·6	68·0	78	19	40	34	28·6
Surface Deposits	138·6	119·1	100·0	107·4	107·4	101·4	109·0
New Red Breccias with shales and marls	245·6	186·11	228·10	62·8	77·8	—	—
Grey Beds	*49·8*	*50·9*	*46·11*	or . . .	or . . .	—	—
Magnesian L'stone and Breccias (highly dolomitic) and red marls	62·4	99·3	216·9	...	...	—	—
Carboniferous Limestone	—	153·6	? 5·6	958·10	656·0	261·8	151·0
Basement Beds	—	—	—	54·8+	99·0+	42·0 (True Conglomerate)	66·0
Volcanic Rocks	23·3+	145·0+	—	—	—	40·0+	24·0 (Fault)
Skiddaw Slates	—	—	86·0+	—	—	—	20·0+

Farther from the hills the lower part of the St. Bees Sandstone series (as proved in a boring, 1,591 feet in depth, upon Haverigg Haws) contains much gypsum, suggesting that—as in the Whitehaven district—there may have been a lateral passage from this gypsiferous series, eastward, into the higher brockrams as the rising land was approached.

South-eastward the Magnesian Limestone is continued into Furness where it attains a thickness of at least 25 feet at Sowerby Wood,[1] and from 63 to 65 feet at Holebeck [2] and Gleaston.[3]

Thinning out of the Brockram.

As above stated, the Brockram thins out in a direction away from the present Fell country. Near Brayton, where it forms the local base of the St. Bees Sandstone, it is only 4 feet thick and rests upon Upper Coal Measures. At Bank End, Maryport, it is 3 feet in thickness, whilst at Blue Dial, about 1½ miles farther north, it is but 3 inches. In both cases [4] it forms the local base of the St. Bees Sandstone, and overlies part of the lower beds of the Coal Measures of that area.

At Barrowmouth its thickness varies from 6 feet to 8 inches, and possibly fails altogether beyond low-water mark. In a boring at Gutterfoot, St. Bees, the lowest brockram is about 11 feet in thickness and is gypsiferous. Conglomerates [? breccias], however, occur, at over 60 feet higher, intermingled with sandstone and gypsum.

After attaining its maximum inland, there is little evidence to what extent the Brockram thinned out eastward, or how far it extended across the higher ground in that direction, but a series of borings put down by the Barrow Company near Tortolocate, east of the Kirk Beck (about 2 miles E.S.E. of Egremont) show a progressive thinning in an easterly direction. Near Egremont it measures about 235 feet; eastwards of the Kirk Beck, however, its thickness over a horizontal distance of 700 yards is progressively as follows: 109 ft. 11 in.; 127 ft. 4 in.; 105 ft. 3 in.; 100 ft. 3 in.; and 70 ft. 8 in.

Eastward thinning of a similar order occurs farther south, a thickness of nearly 350 feet, near Hale, becoming reduced, in 2 miles, first to 270 feet (about half-way), and finally to about 120 feet near Prior Scales, where it is not very far from outcrop.

In general cross-section, therefore, it seems clear that the Brockram is lenticular, and if wholly present would furnish a generalized profile somewhat like that shown in Fig. 3 below.

[1] "Haematites of West Cumberland, etc.": op. cit., p. 23.

[2] "Geology of the Southern Part of the Furness District" (*Mem. Geol. Surv.*), 1873, p. 9.

[3] J. D. Kendall, *Iron Ores of Great Britain and Ireland*, pp. 71, 72.

[4] B. Smith, "On Borings for Coal near Maryport, Cumberland": "Summary of Progress for 1920" (*Mem. Geol. Surv.*), 1921, Appendix III, pp. 86, 89. "On a Boring for Coal at Brayton Domain Colliery, Cumberland": "Summary of Progress for 1919," 1920, Appendix I, p. 52.

The Floor upon which the Brockram Rests.

Hitherto it has been too readily assumed that the floor beneath the Brockram is as smooth and regular as that beneath the Carboniferous Limestone in the Whitehaven area. In some sections in which the underlying platform can be seen, along the Dub Beck, about 250 yards south-west of Millyeat, Frizington (to which Mr. Eastwood drew the writer's attention), for example, the junction is so sharp and clean-cut that one might be forgiven for assuming that the lowest part of the Brockram rested upon a nearly level platform and represented a definite horizon throughout a large tract of country. The Barrowmouth section, although the base is more irregular and invades minor hollows and joints in the Whitehaven Sandstone, does not entirely efface this impression. Other sections, however, definitely prove that the transgression was, in places, across an irregular surface.

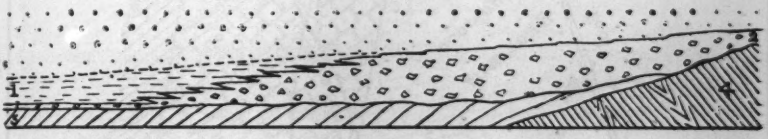


Fig. 3.—Generalized profile of Brockram. 1. St. Bees Shales; 2. Brockram; 3. Carboniferous Rocks; 4. Skiddaw Slates, etc.

In the Mineral Railway cutting between Croft Pit (Bigrigg Mines) and the New Clintz Pit (Townhead Mine) brockram is seen to be stepping rapidly across a rising slope of Carboniferous Limestone (Plate XVII A), which process, if continued for a little distance, would cause an appreciable difference in thickness of brockram at two comparatively near points. Many of the striking disagreements in its thickness in any two neighbouring boreholes in various parts of the district must be ascribed as much to such bottom irregularities as to irregularities at the top of the series, and should with caution be ascribed to faulting.

Another significant feature is the manner in which the buried Carboniferous Limestone, south of Egremont, varies in thickness from point to point. Taking a west-east line from the south of Hale to Prior Scales, the buried limestone, which, south of Hale, averages about 300 feet with its included shales, is reduced in half a mile to about 230 feet, and in little over half a mile farther is practically cut out altogether by brockram. Whether this effect is due to a sudden rapid transgression, owing to an increased rate of rise eastward of the limestone, or to the presence of a buried scarp, is not clear.

A better case can be made out in the Kirksanton area (Table 1 and Fig. 4). It appears that there was here a buried limestone scarp in front of and upon the dip-slope of which brockrams were

accumulated, to be succeeded by magnesian limestone and grey beds which rested directly upon the top of the scarp.

Projecting some of the bores on the line A B (Fig. 4), and arranging so that the base of the grey beds forms a horizontal line, we get the

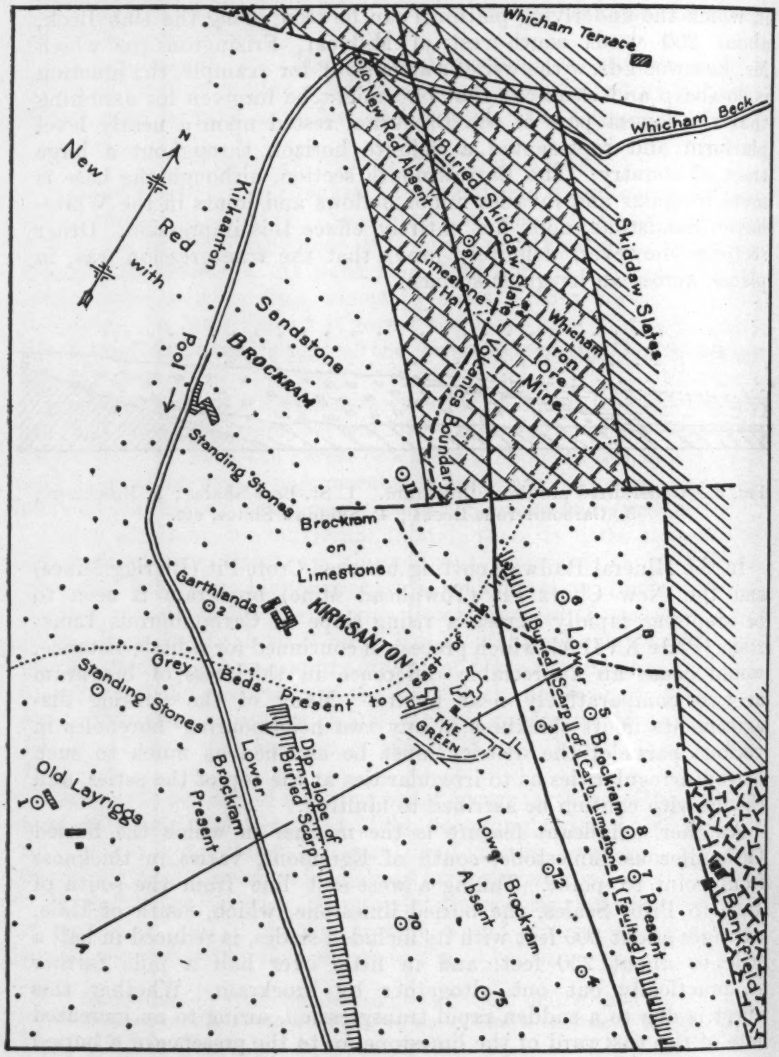


FIG. 4.—Map showing sites of borings near Kirksanton. See also Fig. 5.

surface profile section of this buried escarpment (Fig. 5). The old surface beneath the Carboniferous Limestone is more difficult of

explanation, partly owing to cross-faults, which have been omitted from the map, Fig. 4, for the sake of simplicity. In some cases the occurrence of the old rock surface, in the absence of Carboniferous Basement Beds, may have been due to irregular pre-Carboniferous denudation and deposition about outstanding features; in others it is doubtless due to faulting.

It has been pointed out elsewhere [1] that there is reason for believing that the pre-New Red surface in Furness was of the plateau type (with subordinate scarps)—a kind of Karst Land with underground drainage and rugged surface, and this appears to tally with the conditions that obtained in the West Cumberland area.

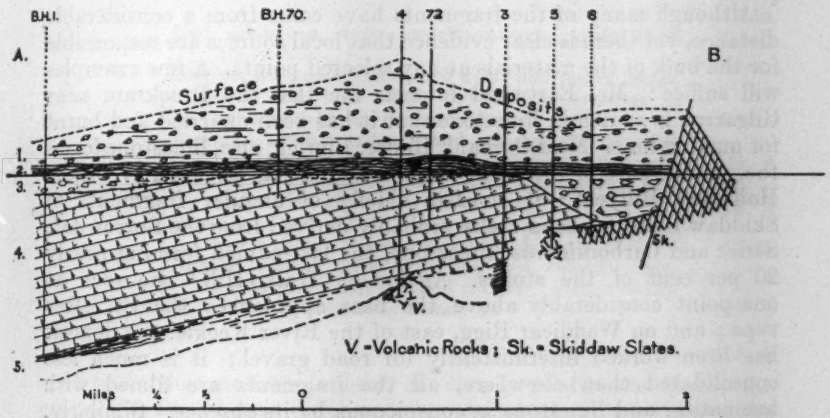


FIG. 5.—Diagrammatic section along the line AB, Fig. 4. 1. Upper Brockram; 2. Grey Beds; 3. Magnesian Limestone and Lower Brockram; 4. Carboniferous Limestone; 5. Basement Beds.

LOCAL CHANGES IN CHARACTER OF THE BROCKRAM AND INTERNAL FEATURES.

Normally the Brockram is a rather tough deposit consisting of many angular to subangular fragments of the various rock types exposed in the district, ranging from Skiddaw Slates to Upper Coal Measures, set in a reddish sandy or muddy matrix. The deposit occurs in posts or beds, like a sedimentary rock, and shows distinct signs of stratification between the larger planes of sedimentation. The rock fragments are set at all angles as a rule, especially where many stones are relatively closely assembled. Where there is a greater proportion of matrix the larger and flatter stones more frequently lie upon their sides. Large isolated stones often have smaller stones and the gritty, sandy, or shaly matrix bedded horizontally against them, as if the larger stones had settled first. Visible signs of torrential action are rare (apart from the general mixture of stones and

[1] "Haematites of West Cumberland, Lancashire, and the Lake District": op. cit., pp. 24, 25.

matrix), though false-bedding is present in places. Deposition from, or in, water is shown by the occurrence of beds of shale and silt. Some of these closely resemble those included in the St. Bees Sandstone; they are frequently micaceous, but usually darker in tint. Certain beds consist of fine grit or sand, derived from the waste of the Volcanic or other Series. The action of water is attested to also by the occurrence of fairly large fragments of Carboniferous Limestone (up to 9 inches or more) with their tops slightly rounded, as if by solution, whilst their bases remain angular. Of all the included stones the limestone fragments are the least angular. Where brockram underlies the Magnesian Limestone it is dolomitized in patches.

Although many of the fragments have come from a considerable distance, yet there is clear evidence that local sources are responsible for the bulk of the materials at any selected points. A few examples will suffice: Mr. Eastwood informs me that the Brockram near Gilgarron is so rich in limestone that it has been quarried and burnt for making lime. Near Orebank House, Bigrigg, also, limestone forms the greater part of the rock. In the Dub Beck, between Weddicar Hall and Millyeat,[1] it consists chiefly of angular fragments of Skiddaw Slate, igneous rocks probably derived from the Borrowdale Series and Carboniferous Limestone, the last-named forming nearly 20 per cent of the stones. Again, at Walk Mill,[1] the rock at one point considerably above the base approaches the St. Bees type; and on Weddicar Rigg, east of the River Keekle, the deposit has been worked intermittently for road gravel; it is much less consolidated than elsewhere, all the fragments are filmed with haematite, and limestone is conspicuous by its absence. Similarly, near Sir John pit, Bigrigg, not far from Orebank House (see above), very few of the included fragments are of limestone. The deposit here is remarkable for the angularity of the fragments, and the included beds of gritty shale or mudstone.

At Barrowmouth the Brockram is noticeable for the varied character and generally well-marked angularity of its components. Some, of Carboniferous Limestone—about 5 to 10 per cent of the whole—are more rounded (and frequently dolomitized); this may be due partly to their soft nature and partly to subsequent solution. The angular and subangular components comprise much material from the Coal Measures (Whitehaven Sandstone, etc.), and a great variety of older Carboniferous rocks. Granitic and quartzitic fragments, cherts, and various types of igneous rock stained red or purple, and angular fragments of green or bluish-green volcanic and slaty rocks are also present. In some layers the fragments are of especially coarse type, and individuals up to 9 inches in diameter may be seen. The matrix is a fairly hard and sandy material, frequently indurated by lime and magnesium carbonate.

[1] T. Eastwood in "Summary of Progress for 1921" (*Mem. Geol. Surv.*), 1922, p. 64.

Thin sandy layers and lines of small stones exhibit a well-marked, albeit somewhat irregular, bedding.

At Ullcoats, near Egremont, the Brockram is largely composed of rock-fragments (averaging ½ to 1 inch in diameter, with a maximum of 3 inches) from the Borrowdale Volcanic Series and Skiddaw Slate, with vein-quartz and Carboniferous Limestone, all set in a more or less stratified matrix of muddy sand. Near Hale volcanic rocks have supplied the greater part of the material, except at the base, where limestone is common also. Here a few examples of Ennerdale Granophyre are to be found.

A typical example at a depth of over 1,000 feet below the present surface is afforded by the following record [1] from B.H. No. 13 Hale :

		ft.	in.
	Red sandstone, with breccia material quite above base.	36 ft.	
Brockram	Breccia, fine, and mixed with shale and marly bands, and shale-beds with "clots" or lenticles of calcareous to sandy material	55	5
	Breccia, medium-coarse, and of general greenish tint owing to preponderance of volcanic fragments	40	1
	Breccia, of general red tint, with some sandy beds and shales with calcareous "clots"	83	9
	Breccia, of red colour, with some green fragments (some shaly), limestone appearing . . .	57	11
	Breccia, coarse, with limestone and volcanic fragments prominent in a red matrix; welded neatly on to Carboniferous Limestone	42	3
		279	5

It is further noticeable how, in closely contiguous bores, the grade of material may differ greatly. As an example we may take Nos. 2 and 3 Prior Scales, 185 yards apart. Here limestone occurred throughout. In No. 2 (219 feet of brockram), apart from one or two boulders of volcanic ash up to 8 inches in diameter, the coarsest breccia consisted of fragments up to 3 inches in size; yet in No. 3 (94 ft. 6 in. of brockram) most of the breccia was an exceedingly fine-grained volcanic sand with occasional larger fragments. The highest part was somewhat coarser, but not so coarse as that in No. 2.

The brockrams of the Kirksanton district are more roughly assorted and consist of red or mottled marls alternating with fine or rough breccias. Both lower and upper brockrams consist to a large extent of limestone, in addition to slate, volcanic and other igneous rocks. They differ only in that the higher usually contain most shale and marl, and the lower are perhaps coarser on the whole and more dolomitized.

Conditions of Formation.

Taking the above facts into consideration, and making comparison with similar, but fairly modern, deposits of which a description is given below, the conclusion is drawn that the Brockram represents the accumulation of a series of torrential fans swept down into the

[1] Published by permission of the Egremont Mining Co.

lowlands from the slopes, gullies, and chasms of a mountain range lying to the east. The angularity of the fragments points to arid climatic conditions; they are the product either of frost action or rapid changes in temperature. The basin into which they were swept may have extended to Scotland or the Isle of Man where a similar series of breccias occurs at the base of the New Red Series, fringing the post-Carboniferous mountains. The floor upon which the greater part of this deposit was laid down was a land surface swept clean of soil or other residual debris, probably by the floods themselves, but perhaps partly by wind. No sign of the tools which cut that denuded platform is visible to-day, but obviously water played a part in its sculpture, if only by solution of the limestone.

The lowland basin held a shallow enclosed sea, into which the fringing breccias were swept tumultuously in nearly flat and mutually overlapping sheets. The water, however, quickly checked the distribution. In this basin the Magnesian Limestone was precipitated and later, as it grew in extent, the gypsiferous marls were accumulated as fringing deposits to the breccia-fans. From the absence of Magnesian Limestone and St. Bees Shales north of Maryport and near Brayton there is some suggestion that the lowland tracts were uneven, and may have held in the early stages a very irregular sheet of water or almost isolated lakes. As time went on the shallow waters of the ever-filling basin steadily expanded and encroached upon the fans, and the area from which the angular debris was derived became constricted. Sand and mud was brought into the basin (most of it perhaps from other districts) and dovetailed with the breccias near the water margin. In time the sands would finally overlap the greater part of the breccias, and might possibly have rested almost directly upon the old land surface and buried it entirely. The thickness of the St. Bees and higher sandstones proved by boring at Seascale,[1] if piled vertically above the Brockram east of Hale, would overtop Sca Fell to-day—without making any allowance for the present seaward dip of the beds.

No enormous boulders, such as might need the occurrence of ice-foot for their carriage, have been found in these brockrams by the writer, and there is no fact to be explained that appears to demand the transporting action of snow or ice at this period.

Comparative Geographical Conditions in Recent and Sub-Recent Times.

The conditions of Brockram formation are paralleled to a certain extent by those existing in such depressions as that of Turfan, in Central Asia, where a mountain-encompassed depression, 300 feet below sea-level and 60 by 25 miles in area, is ringed about by three concentric areas of deposition: (1) outside, a zone of coarse waste

[1] See footnotes, pp. 306 and 307. Professor Gregory suggests that the St. Bees Sandstone material of Seascale was derived from South-Western Scotland.

or piedmont gravel,[1] which buries the lower slopes of the mountains to a great depth and forms a broad barren expanse, like a shingle beach, from 5 to 20 miles wide. Most of the streams gradually lose themselves in its dry porous depths. At its inner edge the gravel zone gives place to (2) a fine clayey deposit forming a smooth plain, which ranges into (3) a saline plain, and finally a playa. In the spring, however, underground water from the mountains converts hundreds of square miles of the plain into impassable muck.

Another example may be taken from Persia, where some of the valleys are over 5,000 feet above sea-level. "The elevated plains or broad valleys, surrounded by mountains of moderate height, are covered in the central part with a fine pale-coloured loam—probably loess, and thus of subaërial origin, though lacustrine deposits exist in places. But from the foot of the hills a fringe of breccia extends over this on either side, for a distance of 3 or 4 miles, and sometimes more, its surface sloping at a very low angle, usually from 1 to 4 degrees."[2] The climate, as in Central Asia, is one of extremes.

Dr. T. O. Bosworth has recently described an interesting parallel in Peru.[3] Here a great belt of breccia produced by periodic floods of Quaternary age, surrounds the Amotape Mountains. Whenever a flood year arrives it finds on every hill-slope and valley-side many years' accumulation of loosened and broken rocks awaiting transportation. Great torrents of mud and stones then sweep down the mountain-sides and pour out from the mouth of every valley on to the plain, where there is a sharp check in velocity and the greater part of the load is dropped.

A contributory cone of breccia has debouched from the mouth of each mountain valley, and these have united to form one large fan, which stretches far out into the plain. The slope, near the mountains, is 2 or 3 degrees, and at a distance of 3 miles away it is about half a degree—the altitude decreasing by one or two hundred feet. The breccia varies in composition according to the sources of the various cones contributing to the fan. It is a massive deposit, with regular—and also current—bedding, consisting of courses of varying character, some with large stones, others made up of small stones, and others again of sand and gravel. The deposit also extends back up the mountain valleys, and their tributaries, filling them completely to a depth of 100 feet or more.

[1] Ellsworth Huntington, "The Depression of Turfan in Central Asia": *Geogr. Journ.*, 1907, pp. 254–73. Professor Huntington informs me that "the 'pebbles' in these piedmont slopes vary from rough angular boulders a foot or two in diameter, close to the border of the mountains, to small well rounded pebbles well out from the mountains, and finally sands and clays. . . The gravels are stratified with the rough stratification which one normally finds in piedmont deposits of dry regions. False- or current-bedding is quite frequent, especially in the coarser gravels".

[2] Bonney, quoting Blanford, "On the Relations of Certain Breccias to the Physical Geography of their Age": *Q.J.G.S.*, vol. lviii, 1902, p. 199.

[3] *Geology and Palaeontology of North-West Peru*, Macmillan & Co., London, 1922, pp. 244–6.

Still more instances are forthcoming from the Western States of America, where the deposits are known variously as " valley-fill " or " fan-glomerates ".

Broad debris-filled valleys lie between parallel ranges in the arid regions of Arizona and Nevada. Typically they have no drainage outlets, but contain playas or alkali flats. In these districts aridity is characteristic of all seasons. Most of the rain for one or more years may fall in a single storm of brief duration, while the sun may be shining a few miles away. Daily changes in temperature produce striking results. They result in rupture and " spalling ", exfoliation, and granular disintegration.

In Arizona [1] canyons cut the bounding ranges, and whilst some carry fairly permanent streams, the majority disappear in dry seasons before reaching the main valleys. These canyons, however, discharge large floods which have built huge fans.

Any given range has canyons that differ amongst themselves in size and character, and its stream-built slope, therefore, is not a homogeneous structure, but a building together of fans of different shapes and sizes. The slope which borders the Chiricahua Mountains of Sulphur Spring Valley is four townships (24 miles) wide, and is of very low inclination. Incidentally, the whole valley is here about 30 miles across—as far as from St. Bees Head to the Isle of Man.

Again, in Big Smoky Valley, Nevada,[2] which is hemmed in by deeply notched mountain walls, an alluvial cone springs from each canyon mouth and differs in size and shape of its concave profile from its neighbours as much as the canyons do themselves. As the latter are not far apart their fans tend to converge and form an almost continuous smooth slope. Large fans of gentle gradient emerge from long canyons that head back into the high mountains and form the outlets of extensive areas of high altitude and heavy precipitation.

The sorting done by the floods is very imperfect. In places the carrying power of the water diminishes so suddenly that pebbles, sand, and clay, sometimes even boulders and clay, are dropped simultaneously. Beds reported by drillers as " clays " contain large proportions of gritty material and small pebbles. They are of a prevailing pale-reddish colour. Nor are the beds reported as gravel clean gravels; they may be pebbles and boulders embedded in clayey matrix. The successive floods from any one canyon differ greatly in size and therefore in carrying power. Hence, fine sediments are thrown down upon beds of coarse debris, and at any given point the drill penetrates successive beds of different character (cf. with section of Brockram, p. 294).

[1] " Geology and Water Resources of Sulphur Spring Valley, Arizona: " Water Supply Paper 320, *U.S. Geol. Surv.*, 1913, by O. E. Meinzer and F. C. Kelton.

[2] " Geology and Water Resources of Big Smoky, Clayton, and Alkali Spring Valleys, Nevada ": Water Supply Paper 423, *U.S. Geol. Surv.*, 1917, by Oscar E. Meinzer.

In the playas, or temporary sheets of water, fine sands and silts, with a central zone of dense clays, are deposited, the latter usually impregnated or overlain by gypsum and other soluble salts. Beneath many of them are stratified clays of great thickness supposed to have been formed in more permanent lakes of the Pleistocene (or even slightly earlier) period. In the San Pedro Valley included horizontally bedded diatomite suggests that the valley was part of an estuary or sea at one time.[1]

Contemporaneously, fan-glomerates, identical with those described above, were being deposited on the valley floors between the lakes and the hills. Hence, although the valleys may at one time have held larger bodies of water than nowadays, *the general arid conditions and the continuous formation of identical fan-glomerates persisted throughout.*

An outcrop of "valley-fill" in the upper part of an alluvial slope in Big Smoky Valley (plate xi of Water-supply paper) may be compared almost exactly with the Brockram of West Cumberland.

Comparative Conditions in the Past.

Comparisons might be made between these West Cumberland breccias and others in the British Isles ranging from Late Carboniferous to Triassic times, such as those of the Bristol district and the Midlands; but the most reasonable comparison is with those of the Vale of Eden; remembering that the greater part of the latter are of pre-Magnesian Limestone age, whilst the greater part of those of West Cumberland were presumably formed later than the Magnesian Limestone of that area. In this connexion we may quote Professor P. F. Kendall's conclusion "that these Permian breccias were laid down as gravel fans by torrential streams emerging from a deeply trenched plateau terminating in a fault-scarp several thousands of feet in altitude".[2]

Comparisons may be made also between the New Red Beds of the Vale of Eden and the above-described Quaternary "valley-fills", with their lake beds, dune sands, and other features.

Classification.

Mr. J. G. Goodchild has registered a protest against employing the term Permian to represent any of the New Red Rocks of Cumberland and Westmorland.[3] He would place the beds below the St. Bees Shales in a Lower Division of the New Red, as distinct from an Upper Division which comprises the St. Bees Shales, St. Bees and Kirklinton Sandstones, and the Stanwix Shales. He points

[1] "Geology and Water Resources of Sulphur Spring Valley, Arizona," op. cit., pp. 57–62.

[2] "The Geology of the Districts around Settle and Harrogate": *Proc. Geol. Assoc.*, vol. xxii, pt. i, 1911, p. 48.

[3] "Observations on the New Red Series of Cumberland and Westmorland, with special Reference to Classification": *Trans. Cumb. and West. Assoc.*, No. xvii, 1892 (Reprint), p. 24.

out that the rocks of the Lower Division are separated from the underlying rocks by a great unconformity, equivalent to the time required for the denudation of some 12,000 feet of older rocks.

In discussing the history of the opinions on the classification of the Cumberland New Red Series, he points out that (1) the whole series was classed with the New Red; (2) later on Phillips and Sedgwick[1] referred the strata above the Magnesian Limestone to the Trias, leaving all below as Permian. (3) Then the St. Bees Sandstone was put back into the Permian,[2] because no unconformity was visible between this thick mass of sandstone and the beds below. (4) Years after, on examination of the rocks by the Geological Survey, all the beds above the horizon of the Magnesian Limestone were again grouped with the Upper New Red (Trias). Goodchild accedes to this classification, although on the larger question of finding "the great dividing line between the Palaeozoic rocks and those of Secondary age" he states: "We *may* find it at the base of the Red Rocks, but it is vain to seek for it in the midst of a virtually continuous series of deposits, formed, from base to summit, under one set of conditions."[3]

Yet he finds a local discordance between the St. Bees Shales ("Bunter Marls") and the Lower New Red in the Vale of Eden, and concludes that if we really must continue to draw a hard line on any horizon through the New Red Series, the position of that line in Cumberland and Westmorland ought no longer to be a matter of doubt.

Goodchild, however, would describe the Lower New Red Series of the Vale of Eden, and its equivalent near Whitehaven, as Dyas, and considered that it was below this Dyas that the division between Secondary and Palaeozoic should be drawn.[4]

Considering now the West Cumberland district, the rocks described so far in this paper consist of one series, to which the Brockram forms a local base and into which the different members of the series pass laterally. But just as the St. Bees Shales pass upwards by imperceptible stages into St. Bees Sandstone (with beds of shale) so the Sandstone, in its turn, passes up by equally, or still more, imperceptible stages into a higher group of sandstones in which there is little shale. These are developed in the plain south of St. Bees and Egremont. Professor Gregory, in interpreting one boring,[5] has correlated these Upper Sandstones with that of Kirklinton, and although (from the examination of numerous bores by the writer) they cannot be so definitely separated from the St. Bees Sandstone as he suggests, and are considered to be

[1] *Geol. Trans.*, 2nd ser., vol. iv.

[2] "On the Permian Rocks of the North-West of England, and their extension into Scotland": op. cit., pp. 144–65.

[3] "Observations in the New Red Series, etc.": op. cit., p. 8.

[4] Op. cit., pp. 14, 15.

[5] "On a Deep Bore at Seascale in Cumberland": GEOL. MAG., 1915, pp. 146–9.

in the main of Bunter rather than Keuper age, this correlation appears to be sound. The comparison has, in fact, been strengthened by our recent knowledge. Beds of pale sandstone, such as can be matched in the Kirklinton Sandstone of the Carlisle district [1]; the presence of a large amount of included wind-blown sand near Calder Bridge [2] (rendering the sandstones similar to some of the Penrith Sandstone), and the occurrence farther south [3] of a deposit of white and yellow sandstones and soft loose sands to a thickness of 1,178 feet on a local base of 75 feet of red marls, shales, and fine breccias, all suggest identity with the Kirklinton group. These sandstones may be compared also with the Upper Mottled Sandstones of the Wirral Peninsula.[4]

In the writer's view—and this conclusion has been arrived at also for the Carlisle and Eden Valley districts by Goodchild [5] and by the Officers of the Survey [6] now re-surveying those districts—these relatively shaleless Upper Sandstones are merely a higher group of sandstones accumulated under shallow-water conditions resembling those under which the St. Bees Sandstone was assembled.[7]

The St. Bees Sandstone is now generally considered to be the time equivalent of the Bunter Pebble Beds, and seams of pebbles [8] occur in it in a sporadic way.

This correlation brings that part of the Brockram of West Cumberland which is dove-tailed into the St. Bees Sandstone into the Trias, and since the whole of the Brockram, as we know it, was accumulated under practically identical physiographic conditions, from its first appearance beneath the Magnesian Limestone upwards, we must conclude that all the rocks contemporaneous with the breccias were formed under conditions so similar that any differences may be ascribed to the local physiography rather than to widespread changes in elevation or climate.

Russell, working in the Whitehaven district, states,[9] in 1888,

[1] *Summary of Progress for* 1921, p. 45.

[2] *Summary of Progress for* 1922, p. 68.

[3] B.H. No. 2, Whitbeck: Surface, 323 ft.; Sandstones, 1,178 ft.; Basement Beds, 75 ft.; Fell Rock (Volcanic), faulted against Skiddaw Slates, 24 ft.

[4] "The Geology of Liverpool, etc." (*Mem. Geol. Surv.*), 1923, pp. 79–81. See also Goodchild, op. cit., p. 7.

[5] Op. cit., pp. 9–10.

[6] "Summary of Progress for 1922" (*Mem. Geol. Surv.*), 1923, p. 60. The views of my colleagues upon the correlation of the New Red and upon the Permo-Triassic sequence will be expressed in the forthcoming memoir on the Carlisle District.

[7] Judging from numerous boreholes the St. Bees facies in the St. Bees–Calder Bridge area, varies between 400 and 800 ft. in thickness, the latter occurring at St. Bees Headland. At Seascale, however, the record showed thick sandstones with only one bed of shale (5 ft.), to a depth of 2,072 ft. 11 in., on sandstone with shale joints or partings to a depth of 3,200 ft. It appears to be impossible to draw a definite line between the two facies.

[8] Goodchild, op. cit., p. 8.

[9] MSS. in possession of the Survey.

that "when we consider the stratigraphical condition of these beds, we find that they all pass gradually either horizontally or vertically, or in both directions, from one to the other. No natural divisions occur amongst these Red Rocks". Murchison, Harkness, and others, also, were impressed by the general continuity of the vertical sequence, even though they had not grasped the fact of the lateral changes. On palaeontological grounds ("if they carried any weight at all") Russell maintained that the rocks should be all (from the St. Bees Sandstone to the basement breccia at Barrow-mouth) Permian.

The Magnesian Limestone contains layers of poorly preserved fossils,[1] amongst which *Pleurophorus costatus* (Brown) is a well specialized form characteristic of the higher part of the Magnesian Limestone of Co. Durham, and widely distributed in the Zechstein of Germany and the Permian of Russia. Hence, if we must make a distinction here between Permian and Trias it should be somewhere above the Magnesian Limestone. The writer, however, is not strongly impressed with the importance of the break described by Goodchild as occurring below the St. Bees Shales in the Vale of Eden.[2] The apparent continuous upward and lateral passage from bed to bed at Whitehaven, coupled with the apparent conformity of the series at Kirksanton, suggests that the break may be local and due to the conditions of sedimentation and the physical form of the enclosed basin or basins, rather than to earth movements. The St. Bees Shales with their gypsum may be correlated on the one hand with the Bunter as Trias, as Goodchild suggested, and as was actually done, or with the Permian, as in the case of the shales overlying the Magnesian Limestone in Co. Durham. Hence, it is thought best at present to consider this episode of shale deposition to represent the change-over period from the Permian to the Trias in this part of the country.

We have, then, the following suggested correlation :—

$$\left.\begin{array}{ll} \text{Trias} & \left\{\begin{array}{ll} f & \left\{\begin{array}{l}\text{Kirklinton Sandstone}\\ \text{St. Bees Sandstone}\end{array}\right. \\ e\text{–}f & \text{St. Bees Shales} \end{array}\right. \\ \text{Permian} & \left\{\begin{array}{ll} e & \left\{\begin{array}{l}\text{Magnesian Limestone}\\ \text{Brockram}\end{array}\right. \end{array}\right. \end{array}\right\} = \text{Brockram, } e\text{–}f.$$

EXPLANATION OF PLATE XVII.

A. Brockram overstepping Carboniferous Limestone (First Limestone) in railway cutting between Croft Pit and New Clintz Pit, south of Bigrigg.

B. Magnesian Limestone overlying Brockram; Saltom Bay, Barrowmouth. Note rock fragments in lowest bed of limestone near hammer.

[1] "Summary of Progress for 1921" (*Mem. Geol. Surv.*), 1922, p. 65.
[2] Op. cit., pp. 11–14.

A

B

Photos H.M. Geological Survey.

A. BROCKRAM ON CARBONIFEROUS LIMESTONE; RAILWAY CUTTING SOUTH OF BIGRIGG.

B. MAGNESIAN LIMESTONE ON BROCKRAM; SALTOM BAY, BARROWMOUTH.

[*To face p. 308.*

The Flint Flakings of the Weybourne Crag.

By S. Hazzledine Warren, F.G.S.

In my Presidential Address to the Geologists' Association I briefly referred to the flint flakings of the Weybourne Crag of the Cromer Coast,[1] to which attention was first directed by Mr. F. N. Haward.[2] During several recent visits I have been greatly impressed with the richness of this site in those remarkable flakings which are now so well known from the Ipswich district.

The basement bed of the Crag, in which the flakings occur, is seen at intervals from the cliff section at Weybourne, to near Cromer, where it falls below sea-level. One can go day by day and collect every time as many true flakings as one cares to carry.

Let us now journey southward down the Bure Valley, leaving the Weybourne or newest of the Crags, and passing towards successively older members of that series. In the Bure Valley the basement bed is still the same with the same types of flakings. All around Norwich, beneath the Norwich Crag, it is still the same. Still further south, all around Ipswich, beneath the Red Crag, the same story is unfolded, while evidence of similar conditions has been recorded from beneath the still earlier Coralline Crag.

The north to south distance of the above-mentioned distribution is about 70 miles. The deposit must have originally extended further to the north, while the occurrence of the characteristic basement bed flakings in the Palaeolithic gravels of Essex, proves its denudation to the south. The east to west extension is also very considerable.

Viewed as a prehistoric floor, the basement bed is less rich than the working sites of Grimes Graves or Cissbury,[3] but if we search the section of the surface soil along the cliff top, we do not find Neolithic axes in quantity as we find rostro-carinates in the section of the basement bed below. It is rather remarkable to find such conditions spread over a vast area of the sea floors of the Coralline, Red, Norwich, Bure Valley, and Weybourne Crags.

The study of the patination of the Weybourne flakings affords important evidence, and shows that they are not of one date. The later flakings sharply truncate the patinated surfaces of the older flakings. No theory of the origin of these flakings can be considered which does not satisfactorily account for the intermittent continua-

[1] S. H. Warren, *Proc. Geol. Assoc.*, vol. xxxiv, 1923, p. 173.

[2] F. N. Haward, *Proc. Prehist. Soc. East Anglia*, vol. iii, 1919, p. 139.

[3] It will be gathered that I take the Crag flakings which are found together as an associated group of common origin, just as one takes the flakings from Chelles, Milton Street, or Le Moustier. Some authorities select a few of the Crag flakes with chipped edges while rejecting the rostro-carinates, with most of their associates. This appears to me equivalent to selecting a few of the scrapers from Grimes Graves for acceptance, while rejecting the axes, cores, etc., from which (broadly speaking) the flakes were struck off. Let it be granted that nature has made nineteen of the flakings, then she can equally make the twentieth, which is a little more attractive.

tion of the flaking process throughout a considerable period of time. Re-worked human implements of two different dates are known in prehistory, but they are very rare. In the basement bed three different periods of flaking on the same specimen are common, and two periods nearly if not quite as common as one. The admittedly human and the disputed groups are in sharp contrast.

On my last visit to the Cromer coast I obtained half a dozen true bulbous flakes and one pseudo-racloir, which had been definitely fractured in situ by the movement under pressure of the superincumbent strata. The flake surfaces of these are for the most part covered by a thin film of mineral incrustation, which has filtered through the crevice between the flake and the core-piece, showing that the fractures are not so fresh as they appear to be at first sight. None of these show any true patination, or alteration of the flint surface. I have quite a number of other flakings which are in the same mineral condition, and therefore they were in all probability made in situ, although this was not proved during the digging.

This later sub-soil flaking doubtless accounts for a good deal of the re-working of the specimens, but it would be difficult to urge this point in favour of the human origin of the earlier flakings, as both are of similar character and follow the same plan.[1]

In the comparative study of the flake characters, my method is to take the known mechanical and the disputed flakings in my hand together, to place them back to back, face to back, and edge to edge, and to compare the details of the forms, curvatures, and angles, point by point. It is my intention to present a properly illustrated account of these comparisons as soon as possible, but it cannot be ready for publication at present.

Although not from Weybourne, one may refer, as an illustration of the kind of comparison in mind, to the sub-soil pressure rostro-carinate illustrated in the *Proc. Geol Assoc.*, vol. xxxiv, 1923, p. 41. Side by side with this let us place one of the best examples of Crag rostro-carinates (alleged to be a human implement) illustrated in the *Proc. Prehist. Soc. E. Anglia*, vol. iii, 1921, p. 416. The drawings are very different in style, but the originals are more alike than they appear to be from the first glance at the figures. The chief real differences are, that the pressure specimen is much the better as a useful implement: it has a superior point, and a larger and more efficient hand-grip at the butt-end. In condition, the pressure rostro-carinate is crude and sharp, whereas the Crag specimen is abraded and smoothed, and this difference in appearance obscures the identity of the plan and method of the flaking. Regarded as if they were human implements, the ideal form which would appear to have been aimed at in the minds of the makers is identical in the two instances.

[1] For the frictional group characters, vide *Proc. Geol. Assoc.*, vol. xxxiv, 1923, pp. 156–60, etc.

It is this underlying plan that deceives. Under suitable conditions the flaking down of broken pieces of flint tends to follow a method which is apparently intelligent, under the controlling guidance, as it were, of certain principles of fracturing which I have named "The Planes of Least Resistance",[1] and of Mr. Haward's "Chip and Slide".[2] The rough analogy of this breaking-down process to the building-up of crystals in geometrical forms, and to the repetition of similar crystalline forms in the same substance, is not so far-fetched as it might appear to be.

To return to the special conditions of the Weybourne Crag. Starting from (1) the proved in situ sub-soil flaking (which may be still going on, though most of it is older than the present time), one can reasonably infer similar frictional action, (2) during the stupendous disturbance of the deposits under glacial action (3) by the grounding of ice-floes, or other agencies of movement, on the floor of the Crag sea. And further, one must not forget the possibility of (4) derivation from earlier deposits in which frictional action would probably have occurred.

That is my theory to account for the intermittent recurrence of frictional flaking upon the basement bed flints, accompanied as it is with abundant striations which indicate the friction which is also capable of effecting the chipping.

I would emphasize the exceptional importance of the Weybourne site in the comparative study of these extraordinary groups of flint flakings of disputed origin. We there find representatives of most of the important groups associated together. There are larger flints battered, crushed, and flaked indefinitely. There is an abundance of rostro-carinates and other core-pieces; while the flake-group removed in making them still remain on the same horizon. That is to say, the heavier and the lighter have not been separated by water transport, but the whole form a complete group of flakings associated together.[3] Many of the flakes have secondary chipping of the edges, in the pseudo-Mousterian or Foxhall style.

The last-named selected pieces (a very small percentage of the whole) undoubtedly present an appealing resemblance to human work, but it is the group characters of the series that impress myself. That is to say, the range of the chipped forms, their variety, and their limitations. And, above all, it is the parallelism of this distinctive group of forms with the proved effects of mechanical action which in my view points to the true cause of their origin by non-human agencies.

[1] For a fuller explanation, *vide Journ. R. Anthrop. Inst.*, vol. xliv, 1914, p. 412; *Proc. Geol. Assoc.*, vol. xxxiv, 1923, p. 39, and p. 153.

[2] F. N. Haward, *Proc. Prehist. Soc. E. Anglia*, vol. i, 1912, p. 189, etc.; vol. iii, 1919, p. 137; also S. H. Warren, as under 1.

[3] For a fuller explanation of a "complete" or "incomplete" group of flakings, *vide Proc. Geol. Assoc.*, vol. xxxiv, 1923, p. 171.

Notes on a New Collection of Fossil Echinoidea from Jamaica.

By Herbert L. Hawkins, D.Sc., F.G.S., Professor of Geology, University College, Reading.

(PLATE XVIII.)

I. Introduction.

SHORTLY after the appearance of my paper on "Some Cretaceous Echinoidea from Jamaica" (Geol. Mag., Vol. LX, 1923, p. 199) Dr. C. T. Trechmann returned from a further visit to the Island, bringing with him a considerable collection of Echinoids. These he has entrusted to me for examination and report, possibly with the hope that the Cretaceous specimens might induce me to change my heretical opinions as to the horizon present! Once again I have to express regret that I can only repay his kindness by expressing views similar to those previously given, and this time with far greater precision than before.

The bulk of the collection consists of Tertiary forms, most of which are from the Yellow Limestone of one locality. The preservation of the majority is tragically bad; but a sufficient number are in beautiful condition. Three new species are diagnosed; but this proportion would probably be considerably increased if some of the forms were less battered.

The twenty-two specimens which compose the collection come from five different localities in Jamaica. The list, as far as I can determine it at present, is as under:—

A. Rudist Limestone, Great River Valley, near Catadupa.
1. *Goniopygus supremus* sp.n. . . 1 specimen.
2. *Hemiaster* sp.indet. . . . . 1 „

B. Yellow Limestone, Spring Mount.
3. *Cidaris* sp.indet. . . . . 1 specimen.
4. *Hebertia simplex* sp.n. . . . 1 „
5. "*Echinolampas*" *ovumserpentis* Guppy 3 „
6. *Echinolampas* sp.indet. . . . 1 „
7. *Rhynchopygus* sp.indet. . . . 2 „
8. *Periaster* sp. (?) nov. . . . . 1 „
9. *Periaster* cf. *elongatus* Cotteau . . 1 „
10. *Paraster* cf. *subcylindricus* (Cotteau) . 2 „
11. *Linthia trechmanni* sp.n. . . . 1 „
12. *Plagiobrissus* cf. *loveni* (Cotteau) . 1 „
13. (?) *Schizaster* sp. (?) juv. . . . 1 „

C. Yellow Limestone, Railway between Cambridge and Catadupa.
14. *Amblypygus americanus* Desor . . 1 specimen.

D. Yellow Limestone, Glasgow.
15. *Paraster* sp.indet. . . . . 2 specimens.
16. *Eupatagus* cf. *antillarum* (Cotteau) . 1 „

E. White Limestone, Montego Bay.
17. *Brissus* sp.indet. . . . . 1 specimen.

The generic terms employed are used, so far as practicable, in the sense of R. T. Jackson, 1922, Carnegie Inst. Pub. No. 306.

The letters and numbers preceding each determination in the foregoing list are quoted against the corresponding items in the next section.

II. Description of the Collection.

A. 1. *Goniopygus supremus* sp.n. (Pl. XVIII, Figs. 1 and 2.)

Holotype (unique) from the Rudist Limestone, Great River Valley, near Catadupa (Jamaica). In British Museum.

Measurements (in millimetres) :—

Diameter	32·7
Height	15·8
Apical system (diameter)	11·6
Peristome (diameter)	(*c.*) 15·1
Periproct (111–5 diameter)	4·3
Ambulacrum (chord on ambitus)	5·4
Interambulacrum (chord on ambitus)	14·0
Number of interambulacral plates per column	10
„ ambulacral „ „	(?) 65

Description :—

Corona slightly crushed; adoral and adapical surfaces almost parallel, ambitus evenly rounded. Ambital outline circular, the faint prominence of the ambulacra counterbalanced by the protuberance of the interambulacral mamelons.

Ambulacra tapering very little adapically, expanding slightly adorally, with almost parallel sides for most of their length. Perradial tract ornamented with two rows of very prominent tubercles situated just within the poriferous zones, continuous from apex to peristome (one tubercle to every four pore-pairs), and an internal zigzag of much smaller granules which fail at a distance of about 3 mm. from the ocular margin, but are elsewhere continuous. The bosses of the tubercles are so steep that the whole structure appears like one hemispherical, imperforate mamelon. There is no other ornament. The poriferous zones are narrow, flush with their surroundings, and practically straight and uniserial to a point about 2 mm. from the peristome, where marked crowding and displacement comes in suddenly. The pores are small and roughly semicircular, those of a pair separated by a prominent ridge or granule. In the expanded peristomial parts the plates seem combined into triads; elsewhere, even to the ocular margin, they form tetrads. The actual course of the sutures within the compounds cannot be traced.

Interambulacra tapering adapically and adorally. The apicad plates support tubercles (one each) similar to, but slightly larger than, those on the ambulacra, and are otherwise bare. Four or five mid-zonal plates in each column have enormously prominent tubercles, with steep bosses, relatively gigantic imperforate mamelons, and very shallow, longitudinally confluent, scrobicules. The remains of the scrobicular circles are restricted to two adradiad secondaries (one at each corner of the plate) and three

(rarely four) interradiad secondaries forming a slight arc in the "miliary" zone. These secondaries are precisely like those of the inner ambulacral series. The orad plates have rapidly diminishing primaries, with a slight increase in the number of small secondaries. There is no miliary granulation on any part of the test.

Apical system fairly large, more or less decagonal owing to the projection of the genitals and oculars. The whole surface is quite smooth, and it is difficult to distinguish the plates. The oculars appear to be all exsert. The genitals are outwardly acuminate in the interradial line; the oculars are alate at their margins, two strong points projecting along the edges of the poriferous zones. The madreporite is scarcely perceptible, but can be traced at the distal point of genital 2. For further characters see under periproct.

Peristome wide (nearly half the diameter of the test), more or less circular, composed equally of ambulacral and interambulacral sections. Narrow, but not deep, branchial incisions notch the border well within the interambulacral portions.

Periproct slightly excentric posteriorly. Markedly triangular with rounded angles in genitals 1, 3, and 5. The corners are bevelled, and in each is a prominent granule which fails to rise above the surface level. The sides of the triangle are somewhat embayed.

Comparisons and horizon.

It is unnecessary to argue for the generic position of this species—it is an ideal *Goniopygus*. That genus has not been recorded from the West Indies previously, so no local comparisons are available. The nearest form *geographically* would seem to be *G. zitteli* Clark from the Comanche Series of Texas. This species (see Clark, 1893, *Bull. U.S. Geol. Surv.*, 97, pls. xviii, xix) is quite different from *G. supremus*, notably in its five-cornered periproct and more abundant minor ornament. It belongs to a distinct section of the genus.

There can be no doubt that the species which shows the closest resemblance to *G. supremus* is *G. menardi* (Desm.) from the European Cenomanian. It is, indeed, hard to find satisfactory differences between the two, and for a long time I considered *G. supremus* as an exceptionally large variety of *G. menardi*. However, the great flattening of the adapical surface in the Jamaican form, viewed in connexion with its relatively enormous size and slightly more profuse tuberculation, have induced me to diagnose it as a new species. But *G. menardi* is exceedingly variable in size, so that the differences I have invoked will probably appear negligible to some critics. Again, *G. supremus* is very like the Cenomanian *G. brossardi* Coquand; this form has rather larger tubercles than *G. menardi*, and in that respect resembles *G. supremus* the more. But the size and proportions of the test are sufficient (especially when supported by geographical considerations) to distinguish the two species. Another comparison may be made with *G. marticensis* Cotteau, from the base of the Senonian of Les

Martigues. This rare form is not known to exceed 18 mm. in diameter, and is proportionately much taller than *G. supremus*. Further, the interambulacral tubercles of the apicad plates in *G. marticensis* are less reduced than the corresponding tubercles in *G. supremus*. All of the other known species of *Goniopygus* that have triangular periprocts seem to be exceptionally minute in size.

Prima facie deduction from these comparisons would place *G. supremus* between the Lower Senonian and the Cenomanian, with a definite tendency towards the latter. There is no intrinsic reason for any consideration of a higher horizon than that to which I ascribed *Heterosalenia occidentalis*, while the new evidence, added to that provided by *Botriopygus rudistarum*, all points to a lower horizon than even the base of the Senonian. I believe that the nearest estimate possible (on Echinoid evidence) for the date of the part of the Rudist Limestones represented is expressed by the name *Turonian*. It can hardly be any higher, and may be a good deal lower.

Here I must express regret for an omission in my previous paper, which, although not published until May, 1923, actually left my hands in December, 1922. In November, 1922, in a paper by T. H. Withers (*Ann. Mag. Nat. Hist.*, 9, x, p. 535), a note on the horizon from which a new Jamaican Crustacean was collected by Dr. D. Woolacott is given. Dr. Woolacott suggests a Turonian age for the deposit, which he describes as a "Rudist Bank". Whether or no this bed corresponds to any part of Dr. Trechmann's "Rudist Limestones" I do not know; if it should prove to do so, Dr. Woolacott has forestalled me in ascribing these beds to the Turonian.

Dr. Trechmann, in critical comments on my previous results, has argued that new species could not be used for stratigraphical correlation; he appears to demand faunal identity (or something near it) before horizons can be compared. On this occasion I provide him with a new opportunity of exercising that line of argument (the validity of which I deny); but in this case it may be pointed out that only the meticulous methods of modern palaeontology prevent this species from appearing under the Cenomanian name of *G. menardi*! Few of the confident, but reckless, "identifications" once so prominent in lists from divers localities could boast of better bases than this. And how much in the way of correlation depends absolutely on such assumed specific identities! For my part, I may confess that I always view with suspicion any list of fossil names in which species are identified without some reservation (I recognize, with satisfaction, that Dr. Trechmann compares more often than he identifies). Especially in cases like this, where the district concerned is remote from that where the earlier-known type of fossil prevails, I demand *proof* of absolute identity, and failing it assume specific difference. But such an attitude in no way lessens the confidence with which stratigraphical deductions

can be drawn. In the case of *G. supremus*, I am prepared to call the specimen " *G. menardi* var.", if it will help Dr. Trechmann to see my point of view! His remark that an assemblage of Mollusca is more reliable than " single species " of other forms (see GEOL. MAG., Aug., 1923, p. 346) is now rather out of date—there are four Echinoid *genera* available, and all give consistent evidence.

In my previous paper I was content to leave the Rudist Limestone horizon at or about the base of the Senonian, in an endeavour to reconcile the Echinoid evidence with the belief in the Maestrichtian age of the deposit. But in so doing I strained the evidence to its topmost limit. In the light of this new information, *H. occidentalis* and *B. rudistarum* must accompany *G. supremus* into the Turonian, if not to the Cenomanian—a much more congenial position for them. This correlation applies, of course, only to that part of the Rudist Limestone from which these Echinoids were collected. The series of strata between the *Barrettia*-beds and the Eocene seems sufficiently thick to allow of representation of more than one stage, quite apart from the assumed unconformity at the top of the Cretaceous.

A. 2. *Hemiaster* sp.indet. (Pl. XVIII, Fig. 3.)

Rudist Limestones.

A solitary specimen, partly encrusted with a greyish calcareous matrix, is labelled in the same terms as the foregoing species. It evidently comes from a different layer in the series. In as far as they are determinable, the following dimensions give an idea of its qualities; but too little in the way of detail is visible to make possible (or fruitful) any comparisons with other types.

	mm.
Length (all over)	22·3
„ (allowing for anteal sulcus)	21·0
Greatest breadth (about the middle)	21·0 (?)
Height (at apical system)	14·6
Labral point to anterior margin	5·7
Greatest width of plastron	9·1
Anterolateral petals (length)	(c.) 9·3
Posterolateral „ „	(c.) 4·7

The petals are fairly deep, and the anteal sulcus extends as a deep groove right up to the apical system. The anterolateral petals are directed transversely at the proximal end, then anteriorly, splaying again distally. The posterior surface is inclined. The highest point of the test is just above the periproct; the base is tumid, chiefly owing to prominence of the plastron. The peripetalous fasciole is clearly visible at several points, and seems unusually broad where it passes the distal ends of the anterolateral petals.

While admitting that this specimen is non-committal as regards horizon, I can repeat the remark made on the similarly indeterminable Hemiasters noticed in my former paper—the general facies suggests an horizon well below the Senonian.

B. 3. *Cidaris* sp.indet.

Yellow Limestone.

This specimen consists of two contiguous interambulacral plates. These are much worn where exposed, and hopelessly embedded otherwise. All that can be said with certainty is that they do *not* belong to *C. foveata* Jackson, which has deeply crenulate tubercles. This form is obviously destitute of any crenulation. *C. foveata* is the only Cidarid yet described from Jamaica (its type locality), so that there are two species in the Yellow Limestone.

B. 4. *Hebertia simplex* sp.n. (Pl. XVIII, Figs. 4 and 5.)

Holotype (unique) from the Yellow Limestone (Middle Eocene ?), Spring Mount, Jamaica. In British Museum.

Measurements (in millimetres) :—

Diameter	15·0
Height	8·2
Apical system (diameter)	2·7
Peristome (diameter)	6·0
Periproct (diameter)	1·6
Ambulacrum (chord on ambitus)	3·3
Interambulacrum (chord on ambitus)	5·7
Number of interambulacral plates per column	11
„ ambulacral „ „	44

Description :—

Corona subpentagonal in ambital outline, flattened above and below, very tumid at the sides.

Ambulacra straight, lanceolate, widest at the ambitus, forming the angles of the outline. Perradial tract with a double row of perforate tubercles, one on each third plate, never attaining large size, and diminishing above and below the ambitus. A few exceedingly minute granules occur sporadically between these tubercles perradially, but the greater part of the intervening space is bare. Poriferous zones perfectly straight, flush, pores uniserial except just near the peristome, where one or two sets of three deviate slightly from the direct line. Pores in each pair relatively large, elliptical, separated by a small acuminate granule. Plates evidently grouped or combined into dyads with intervening primaries, but sutures indistinguishable.

Interambulacra less than twice the width of the ambulacra ambitally, tapering very slightly adapically, rather more rapidly adorally. Each plate supports one fairly prominent primary tubercle placed quite near the adradial suture. One or two ambital plates support very small secondaries near their interradial sutures. A sparse granulation of small scale is the only other ornament, so that the areas appear very bare.

Apical system small and slender, slightly below the level of the surrounding corona. Plates sparsely granulate, oculars I and V insert, ocular II almost insert. Madreporite covering most of genital 2.

Peristome small, practically circular; margin equally divided by deep and very narrow branchial incisions, which are practically on the adradial sutures and have sharply recurved edges.

Periproct markedly excentric posteriorly and towards radius I. Roughly hexagonal in outline.

Comparisons and horizon.

There seems no question but that this small form agrees closely with the series of Eocene species grouped under *Hebertia* of Michelin by Lambert (i.e. *Echinopedina* of Cotteau). The probability is that its simple characters are due to immaturity, as it is considerably smaller than its congeners. Cotteau, in 1881, described *Echinopedina cubensis*, a form (represented by several specimens) from the assumed Eocene of Cienfuegos, Cuba. Lambert seems not to mention this species, but it must be surely classed with *Hebertia* as he interprets that genus. The Cuban species is nearly three times larger than the form just described; and in view of that fact I regard *H. simplex* as a provisional species only, for it may prove to be the young of *H. cubensis*. However, the fair size of the genital pores in *H. simplex*, and the full reduction of the apical system, are suggestive of some degree of maturity. The genus *Hebertia* is essentially restricted to the Eocene, and its type (*H. gacheti*) and most of its species occur in the middle part of that period. One may therefore assume that *H. simplex* indicates a mid-Eocene date for the part of the Yellow Limestone in which it occurs.

In passing it may be noted that the worn specimen from the Miocene of the Dominican Republic, referred by Jackson (1922) to *Echinopedina cubensis*, is certainly not congeneric either with *H. cubensis* or *H. simplex*. It has strongly triserial pore-pairs. As a result, the doubts as to the horizon of Cotteau's species raised by its reputed occurrence in the Miocene have no foundation.

B. 5. "*Echinolampas*" *ovumserpentis* Guppy.

This well-known West Indian form, perhaps the most abundant and widely distributed of all fossil Echinoids in that region, is represented by three excellent specimens—two perfectly typical in proportions, one rather narrower and more acuminate adapically. Jackson (1922) comments on the variability of this species. It has already been recorded from Jamaica, and is everywhere characteristic of the West Indian Eocene.

The striking dissimilarity of *E. ovumserpentis* from other species of this unwieldy genus is such that its retention in *Echinolampas* is evidently wrong. I very much doubt if it is at all closely related to that group. But at present I am unable to devote sufficient time to unravelling the systematic knots into which the genus has become involved, and I quote the species under its familiar and original title.

B. 6. *Echinolampas* sp.indet.

A much worn and battered specimen, encrusted on the apex. It is about 80 mm. long, 70 mm. broad, and 35 mm. high. The characters visible show it to be a true *Echinolampas*, comparable roughly with such a form as *E. kleini*. It seems quite unlike any West Indian species described by Jackson, and is very likely new. Most species of *Echinolampas* of similar size are of Oligocene date, but there seems no particular reason why this species should not have lived earlier.

B. 7. *Rhynchopygus* sp.indet.

There are two specimens of *Rhynchopygus* in the collection, one fairly large (32 mm. long) but decapitated, the other smaller (23 mm. long, 19 mm. broad, and 14 mm. high). The genus seems not to have been recorded previously from the West Indies; but I am confident of the correctness of the determination. The species (which is most probably new) shows many points of resemblance to *R. lyelli* (Conrad) from the Eocene of Georgia.

B. 8. *Periaster* sp.nov.

A very large, battered Spatangoid measuring about 67 mm. in length by 60 mm. in breadth. No ornament remains, but it is possible to recognize that the four lateral petals were closely similar in length, practically straight, and that the petaloid pores were widely separated, with a groove linking each pair. If this is really a *Periaster*, it is utterly unlike *P. elongatus* Cotteau, the only species yet described from the West Indies.

B. 9. *Periaster* cf. *elongatus* Cotteau.

The miserably preserved specimen (worthy to rank with the holotype itself) seems to agree in all visible characters with Cotteau's species, which was collected in the Eocene of St. Bartholomew. The anteal sulcus is perhaps less deep adapically than in the type; but otherwise there is little ground for distinguishing the two.

B. 10. *Paraster* cf. *subcylindricus* (Cotteau).

Two specimens in a fair state of preservation, which seem to differ from Cotteau's figure merely in a slight curvature of the anterolateral petals. The larger specimen is distinctly "subcylindrical", the smaller rather more rounded. This latter may be Jackson's "*Paraster* sp. *a*", which was collected in Jamaica. He compares his unnamed species with *P. subcylindricus*, and describes it as being "quite near" that species. Cotteau's specimen came from the lower part of the Eocene in St. Bartholomew.

B. 11. *Linthia trechmanni* sp.n. (Pl. XVIII, Figs. 6 and 7.)

Holotype (unique) from the Yellow Limestone (Middle Eocene ?) of Spring Mount, Jamaica. In British Museum.

Measurements (in millimetres) :—

Length (all over)	45·0
„ (allowing for anteal sulcus)	42·7
Breadth (at amb. II and IV)	39·3
„ „ I „ V)	32·8
Height	26·2
Petal II (length)	23·1
„ I „	16·8
Point of labrum to anterior margin	8·1
Number of pore-pairs in petal II	43 or 44
„ „ I	36 or 37

Description :—

Corona cordate, inflated above, almost flat below, sides well rounded. Highest point practically central, greatest width (43·3 mm.) corresponding with interambulacral columns 1*b* and 3*a*, almost equal to all-over length. Anteal sulcus deep, with splayed sides, but petal III shallow. Interambulacra all subcarinate adapically, area V more sharply than the rest.

Petals.—I and V lanceolate, almost straight, directed more backwards than transversely, making area V very narrow. Deeply excavated, with vertical or overhanging sides. Greatest breadth (4·2 mm.) half-way along. I and IV similar, about one-third longer than the other pair, and slightly broader (*c.* 5 mm.), directed transversely and a little anteriorly, perfectly straight. III shallow, granular, with small but distinct pores, attaining full width (4·5 mm.) very near the apex, and maintaining it to the fasciole. Periplastronal parts of areas I and V almost smooth, hardly sunken.

Interambulacra with almost uniform adapical ornament, which becomes slightly coarser on the sides of petal III. Below the ambitus the tubercles increase suddenly in size. Plastronal tubercles considerably smaller than those of the lateral regions of the adoral surface. Plastron lanceolate, tapering quite regularly to the labral tip.

Apical system missing, apparently sunk below surrounding part of the test.

Peristome with sharp labrum, strongly anterior. Details not accessible.

Periproct at the top of a low, almost vertical posterior surface. Elliptical, apparently rounded above and below.

Fascioles.—A clearly defined, continuous *peripetalous* fasciole embraces the distal ends of the petals. In areas I and IV it is embayed to a point very little distant from the apex. In areas II, III, and V the inflection is much less. A *latero-anal* fasciole branches from the peripetalous fasciole in the anterior parts of areas I and IV, and thence passes backwards almost straight towards the periproct. Just before reaching that aperture it turns sharply downwards, and encircles the sides and base of the posterior surface. The peripetalous fasciole is the wider of the two, and has its maximum width (about 0·75 mm.) at its loops round the ends of petals II and IV.

Comparisons.—This unique specimen is by far the best of all the Spatangoids in the collection. I have placed it in *Linthia* on account of its general facies and the course of its fascioles. It is unfortunate that the apical system is wanting. The only species recorded by Jackson from the West Indies with which it is possible even remotely to compare this form is *Paraster antillarum*, but the almost negligible anteal sulcus in that species, and the curved course of the anterolateral petals, are enough to separate the two at a glance. *L. trechmanni* is certainly not a *Paraster* as that genus is interpreted by Jackson. The species to which *L. trechmanni* seems to make the nearest approach is *L. wilmingtonensis* Clark, from the Eocene of New Carolina (see Clark and Twitchell, 1915, *Mem. U.S. Geol. Surv.*, vol. liv, pl. lxx, fig. 3). The greater length and more direct course of the posterolateral petals in the Jamaican species, and its less sunken anterior petal, are sufficient specific distinctions; but the size, shape, and general features of the two are very similar. No species of *Linthia* seems to have been recorded previously from the West Indies.

B. 12. *Plagiobrissus* cf. *loveni* (Cotteau).

A broken and encrusted relic of a once magnificent Spatangoid seems referable to this species. According to Jackson, the holotype (from the Eocene of St. Bartholomew) is the only other specimen known. This example is rather smaller, measuring only about 90 mm. in length (as against 110 mm. in the type) and about 80 mm. in breadth (type, 100 mm.). Its height will have been about 35 mm. The periproct is very large, and seems to have been set in a recess of the posterior margin. The peripetalous fasciole is very narrow but perfectly distinct, and encloses most of the adapical surface, which is thickly scattered with large perforate tubercles. The narrowness of the fasciole is in contrast with Cotteau's description, which comments on the width of this structure. Whether the difference is of specific value or not I do not know; but the resemblances between the two forms are so many and so close that it is only proper to identify them provisionally.

B. 13. ? *Schizaster* sp.juv.

Except that this specimen is obviously immature, there is little that I can say about it. It *may* be a *Schizaster*, but in its present condition it might even be a young *Paraster*.

C. 14. *Amblypygus americanus* Desor.

The discovery of this specimen is peculiarly interesting, since the holotype came from Jamaica, and has not yet been figured. Another specimen in the British Museum seems to make up the full number of known examples. Unfortunately, the specimen in this new collection is very imperfect, practically half having disappeared, and the base being very seriously encrusted. The transverse

diameter is approximately 90 mm. (as in the type), and the height about 40 mm. (slightly more than in Desor's specimen). The comments made by Duncan and Sladen (1883, *Pal. Indica*, ser. XIV, vol. i, pt. iv, p. 13) are fully borne out by study of the new specimen. The concavity of the adoral surface is extreme, but it may have been somewhat exaggerated by compression. The typically Pyrinid ambulacral plating is clearly shown, both within and without the petaloid parts.

D. 15. *Paraster* sp.indet.

Two small, wretchedly preserved specimens seem to represent this genus at Glasgow (Jamaica). They agree, in so far as they show anything at all, with Jackson's account of his " sp. *a* ". Their outward form resembles that of the smaller of the two specimens from Spring Mount—they are probably variants of *P. subcylindricus*.

D. 16. *Eupatagus* cf. *antillarum* (Cotteau).

A much worn specimen of *Eupatagus* seems intermediate in form between *E. antillarum* and *E. clevei* (Cotteau). Both of these are Eocene species from St. Bartholomew.

E. 17. *Brissus* sp.indet.

This specimen from the White Limestone is a broken, partly recrystallized, internal cast, which shows one or two small patches of test adhering to the adoral surface. It is very similar in size, shape, and visible characters to the familiar *B. unicolor* of the Mediterranean. Its large size (about 65 mm. long, 52 mm. broad, and 35 mm. high) make it impossible to identify it with *B. exiguus* Cotteau, which is relatively minute. However, *B. exiguus* shows more than one feature suggestive of immaturity ; so that this form may perhaps be its adult stage. *B. exiguus* is from the Oligocene of Anguilla ; and, although indeterminable, this specimen may be taken as favourable to the idea that the White Limestone is of Oligocene date.

III. General Considerations.

It is a matter for gratification that I achieve perfect agreement with Dr. Trechmann as to the horizon of the Yellow Limestone of Jamaica. The Echinoid evidence is, individually and collectively, in favour of a Middle Eocene age for this limestone, with tendencies downward rather than upward. (See Trechmann, 1923, Geol. Mag., Vol. LX, p. 344.) Further, the evidence, such as it is, from the White Limestone, is consistent with an Oligocene date. May I venture to hope that my apparent sanity in this respect may induce him to take more seriously the conclusions forced on me by study of the Cretaceous Echinoids ? For my own part, I have more confidence in my capacity to appreciate Mesozoic forms than those from the Cainozoic, owing to greater experience. I repeat here, by way of summary (not as an extra act of aggression), that the

Echinoids indicate the Turonian as the highest reasonable stage for the Rudist Limestone.

A very striking negative quality of the Tertiary collection is seen in the absence of Clypeastroids. This character, in a district such as the West Indies (almost a metropolis of the order from the Miocene onwards), is of itself an indication that the Yellow Limestone is low down in the early Cainozoic; and, indeed, gives more than a suggestion that it does not reach to the top of the Eocene.

Another feature, of more general interest and importance, is found in the relative scarcity of Regular Echinoids. This was pointed out in the case of Cuban faunas by Cotteau in 1881 (*Ann. Soc. Belge*, ix, Mém.). In his list, a solitary Diademoid (Centrechinoid) occurs with seventeen Irregular species. In the present collection, in spite of the absence of Clypeastroids, two Regular Echinoids (one a Cidarid) are associated with at least thirteen Irregular species. Such proportions are far from those shown in recent faunas, whether in the West Indies or elsewhere. In the course of research on the Tertiary (mainly Lower Tertiary) Echinoids of New Zealand the same disproportion has become manifest. I have before me eight trays full to overflowing with Irregular Echinoids (mostly Spatangids), and one tray partly filled with all the Regular forms yet collected in New Zealand. Further, the latter few specimens seem to represent but three or four species (two at least being Cidarids), while there appear to be scores of species in the Irregular pile. I believe these conditions to be very general in Lower Cainozoic faunas.

The difference cannot be ascribed to the vagaries of preservation—in my experience the few Regular forms are often excellently preserved, while the Irregular ones are distressingly fragmentary. I am inclined to think that the feeble representation of Diademoids (Centrechinoids) in the Lower Tertiaries is due to a real scarcity. A comparable lack of Echinoids generally is met with in the interval between the Permian and the Toarcian, preceded and followed by abundance and variety. It is possible to explain this early Mesozoic scarcity by the knowledge that the Palaeozoic Perischoechinoidea had worked themselves out, while the orders of the Euechinoidea were still "germinating". In the case of the Lower Cainozoic lapse, conditions similar, though less comprehensive, can be demonstrated. The dominant Mesozoic groups (such as the Hemicidaridae, Diplopodiidae, Holectypoida, and Nucleolitoida) collapsed into relative insignificance before the end of the Cretaceous period; while at that time the essentially modern Echinidae, Echinometridae, Strongylocentrotidae, Temnopleuridae, and Clypeastroida had hardly passed their "probation stage". But by then the "Cassiduloids" and Spatangoida had attained considerable importance, having become established during Cretaceous times.

In the early part of the Mesozoic era, when the Perischoechinoid

rapids had sunk to rest, the persistent undercurrent of the Cidaroida alone prevailed to carry forward Echinoid traditions. That smooth stream maintained its unruffled flow through the opening periods of the Cainozoic era (and bids fair to outlast all its more turbulent branches); but at that time it was almost hidden beneath a frothy torrent of exuberant Spatangoids. Not until the beginning of the Miocene period did the restrained eddies of Echinid currents rise to the surface in volume sufficient to ripple the stream of Evolution.

EXPLANATION OF PLATE XVIII.

FIG.

1.—*Goniopygus supremus* sp.n. Adapical surface. Owing to a mistake in lighting, the uppermost ambulacrum is No. I.

2.—*Goniopygus supremus* sp.n. Adoral surface. (Same orientation as in Fig. 1.)

3.—*Hemiaster* sp.indet.

4.—*Hebertia simplex* sp.n. Adapical surface.

5.—*Hebertia simplex* sp.n. Adoral surface.

6.—*Linthia trechmanni* sp.n. Adapical surface. The course of the fascioles is indicated on the left side.

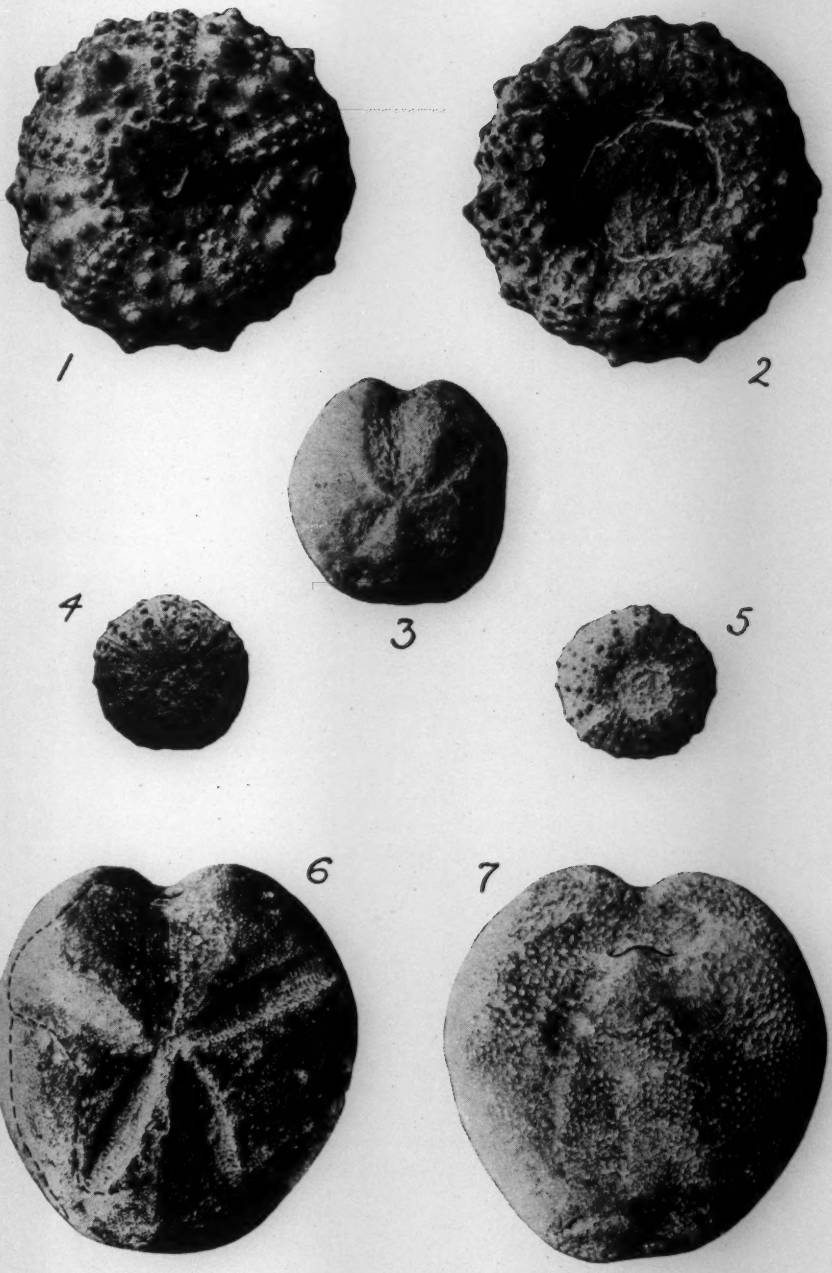
7.—*Linthia trechmanni* sp.n. Adoral surface.

All figures except 6 and 7 slightly enlarged; for true dimensions see description.

A Further Study of the Nomenclature of Rocks.

By A. K. Wells, M.Sc., F.G.S.

IT is hardly necessary to point out how very important it is that those on whom falls the onus of naming a rock should decide which is the most fitting name only after very careful consideration. Some there are who profess to be above the petty worries of nomenclature, and from these only a loose application of rock names can be expected. This is liable to mislead those dealing with problems of petrogenesis, who are justified in assuming that those competent to carry out geological research are also competent to apply correct names to their discoveries. That this is often not the case can be easily demonstrated from quite recent papers. The difficulty arises from two causes: the lack of a system of rock classification which in any sense approaches the ideal, and a desire for brevity. Concerning the first difficulty it is sufficient to say that little advance in placing the nomenclature of rocks upon a firm and common basis is possible until one universally recognized system of rock classification is in use. It is still open for investigators to choose, without any set standard, which of several variable characters of a rock should be the criterion upon which the systematic position of the rock depends. Thus, one writer places mode of occurrence before micro-structure, while his neighbour deems it wise completely to ignore mode of occurrence and makes micro-structure the deciding factor. Who is in the position to declare the one right and the other wrong? Concerning the desire for brevity, this principle, laudable in most other circumstances, is a



H. L. H., Phot. & Del.

CRETACEOUS AND TERTIARY ECHINOIDS FROM JAMAICA.

[*To face p. 324.*

frequent source of error in rock naming. It is often the case that a writer is concise to the degree of incorrectness. Why should it be considered a petrographical sin to use more than one word for a rock name, when by so doing a clear impression of the chief characters of the rock are conveyed to the reader? Would organic chemists consider for one moment the replacement of their league-long descriptive names by others much shorter perhaps, and based shall we say on the name of the discoverer or the place of discovery of the substance? One can well imagine the storm of protest which would arise were such a proposition mooted. Yet the nomenclature of petrology bristles with incomprehensible and therefore useless names based upon an outlandish spot whose whereabouts can only be discovered with the aid of a good atlas and gazetteer. The difficulty would be largely discounted if the recommendations of the Committee on Nomenclature [1] were generally accepted.

To illustrate our sins of omission and commission in this respect the various interpretations placed upon *mugearite* will be briefly reviewed.

The special features of the original mugearite of Skye as defined by Harker [2] are as follows: A marked preponderance of alkali felspars, chiefly oligoclase with some orthoclase, is coupled with a deficiency of coloured minerals, olivine being distinctly in excess of augite. Of the accessories, apatite is abundant, while a little brown hornblende and biotite of the same colour occur. Texturally the rock is trachytic with a highly developed fluxion structure. Mugearites of Tertiary age have also been described from other islands of the Hebrides including Eigg, Muck, Rum, and Canna,[3] and approximate very closely to the type rock, the only notable variation being in the proportion of olivine to augite. In all these occurrences the mugearite occurs as the lower component of multiple sills, the upper and older portion being olivine-dolerite.

Although the mugearites of the Midland Valley of Scotland are different both in age and in mode of occurrence, being lava flows of Carboniferous age, they reproduce down to minute details the characters of the type rock. The brown weathering, platy structure, shimmering lustre due to an eminently perfect flow structure are seen again in the Scottish examples, which are again associated with basalts.[4]

Dr. H. H. Thomas' descriptions and figures of those of the Skomer Island volcanics to which he applied the name mugearite leave one in no doubt whatever that these are also very like the type rock and once again grade into normal olivine-basalts.[5] Variations from

[1] *Report on British Petrographic Nomenclature*, 1921.
[2] "Tertiary Igneous Rocks of Skye": *Mem. Geol. Surv.*, 1904, p. 264.
[3] "Geol. of the Small Isles of Inverness-shire": *Mem. Geol. Surv.*, 1908, p. 130.
[4] "Summary of Progress": *Mem. Geol. Surv.*, 1907, p. 114.
[5] *Q.J.G.S.*, vol. lxvii, 1911, p. 201.

the original rock include the absence of hornblende and biotite, and the sliding-scale relationship of augite to olivine. It follows therefore that during the Ordovician, Carboniferous, and Tertiary volcanic episodes basic rocks differing but little from the mugearite of Skye have been produced. Examination of hand specimens and of thin sections shows that it is not possible to differentiate between intrusive and extrusive specimens. Nothing would be gained by using two names for the two varieties. Bearing in mind the fact that these rocks are basic lavas or fine-grained intrusives, and remembering also the dictates of the above-mentioned committee, it would be hard to find a more suitable general name for these rocks than *oligoclase-basalt*.

It must be clearly understood that *oligoclase-basalt* and *mugearite* are not synonymous terms. The former is a more general term than the latter—the name of a genus which doubtless includes several species of which, at present, only one has been defined—the Mugeary type. The latter is a species of oligoclase-basalt with perfectly distinctive features which impart to it a striking individuality of its own. Stripped of its special characteristics the rock is of the Mugeary type no longer, but merely an oligoclase-basalt of another species. Provided that petrogenetic considerations allow, all basic lavas of like mineral composition should be so named.

It was for the sake of consistency that the writer suggested renaming the Derbyshire lavas which Mr. Sargent named *spilites*.[1] These Derbyshire rocks contain exactly the same minerals as mugearite; they occur as one member of multiple flows, the other being normal olivine-basalt. Dr. Flett has pointed out in what respects mugearite and spilite differ,[2] but apparently these differences have not been comprehended. In no spilite yet described is orthoclase an important constituent, in one example only does olivine occur in notable amounts, in all the rest the only coloured mineral having originally been augite or rhombic pyroxene. In no province yet investigated does spilite occur so intimately associated with normal calcic basalts. In the writer's opinion there is no justification for calling these rocks by any other name than oligoclase-basalt. If the minor features are sufficiently distinctive from those of the Mugeary type, the Derbyshire rocks could be distinguished by another type-name. That discrimination in the use of the two names under discussion is a matter of importance is emphasized by the appearance in a textbook which will be widely read by students, of the unqualified statement that lavas of spilitic type occur in Derbyshire,[3] while an American writer uses the presumed occurrence of "spilites" so closely associated with normal basalts as an argument against the recognition of spilites as distinct from

[1] "Lower Carb. Spilites in Derbyshire": *Q.J.G.S.*, vol. lxxiii, 1917, p. 11.
[2] *Summary of Progress for* 1907, p. 126.
[3] *Introduction to Stratigraphy*, 1923, p. 137.

basalts. Evidently wrong deductions may easily be drawn from the unwise use of a rock name.

On the other hand, to name all oligoclase-basalts *mugearites* is equivalent to calling all nepheline syenites *miascites* or all felspar *microcline*, or all song birds canaries. Yet by Iddings, who groups mugearites with oligoclase-andesites, we are gravely told that "it is advisable to use the name *kohalaite* for all oligoclase-andesites".[1] The rock so misnamed may be sufficiently distinctive to justify the erection of a special "species type" to include it, but to advocate the disuse of a good self-explanatory term in favour of a meaningless place name is absolutely without justification. It is not common sense. As a further illustration it may be noted that a modification of the Newton Abbot dolerite has recently been claimed as mugearite, this name being used "as a generalized term for oligoclase-dolerites".[2] Apart from the fact that this is another case of putting the cart before the horse, the published description and photomicrograph and examination of the slides shows that there is considerable divergence from the type rock whose name is used, both in mineral composition and in texture. The difference in texture is just that between a medium-grained dolerite and a fluxional basalt. By analogy, the Newton Abbot rock is an *oligoclase-dolerite*, and its peculiarities may be of sufficient importance to justify the use of the words "Newton Abbot type".

Finally a plea may be made for the wider use of well-known and firmly established group names, coupled with the word "type", preceded by the name of the type locality as in the examples given above. It is recognized that the principle may be somewhat difficult to put into practice, especially as there is no general agreement as to what amounts to a specific difference. But this difficulty has been overcome in the case of palaeontology, and the determination of a species is a matter of almost mathematical precision. Will not someone in authority lay down the law in this matter, and state dogmatically what differences in composition and texture, and considered in what order, shall be of sufficient importance to justify the erection of a new species of rock?

Since the above article was written in the summer of 1923, Washington has expressed similar views. He advocates the separation of andesite from basalt on the basis of the proportion of salic to femic minerals, further subdivision being determined by the predominant character of the plagioclase present in the rock. "We shall thus have oligoclase-andesite, andesine-andesite, labradorite-andesite; oligoclase-basalt, andesine-basalt, and labradorite-basalt."[3]

[1] Idding's *Igneous Rocks*, vol. ii, 1913, p. 193.
[2] Shannon, *Q.J.G.S.*, vol. lxxviii, 1922, pp. 267, 270.
[3] H. S. Washington, "Petrology of the Hawaiian Islands, 1, Kohala and Mauna Kea, Hawaii": *Am. Journ. Sci.*, 1923, p. 470.

Notes on the Gravels of the Gt. Ouse Basin.

By J. T. Banton, Sometime Scholar of Pembroke College, Cambridge.

FOR some years past I have paid much attention to the gravels of the Bedford and Cambridge areas, and believe that my observations will be of value as bearing upon palaeolithic classification and the question of correlation.

A. Bedford Ouse District.

1. *Willington.*—A gravel has been worked for many years close to the railway station at a level of only a few feet above the river, and apparently belonging to the lowest terrace. It is very even-bedded and has yielded the molar of *Elephas primigenius* and also an implement of Chellean type. The latter is a lustrous orange-brown pointed implement, with thick butt, 4½ in. long and somewhat waterworn. (2) A dark lustrous brown flake, much waterworn, is also said to have come from Willington. These are probably older than the deposit.

2. *Harrowden.*—This pit is about a mile south of Bedford at a much lower elevation than the Biddenham pits and a much shallower deposit. The gravel is evenly bedded and varies from 6 to 8 feet in thickness. Among the few implements obtained is a thick-butted coup de poing 3 inches long, cream-coloured, with superficial orange stains, of late Acheulean or early Mousterian (Micoque ?) type, quite similar to certain implements recorded by Professor Marr from the Traveller's Rest pit at Cambridge (*Q.J.G.S.*, vol. lxxv, 1920, p. 217, fig. 4).

3. *Biddenham.*—This section is best known through the researches of Mr. Wyatt and Sir Joseph Prestwich. Sir John Evans also gives a description of this pit and its contents in his work *Ancient Stone Implements*, 2nd edition, pp. 530, 536. Unfortunately, no recent list of the mollusca and mammalia contemporaneous with the deposit appears to be available. The lists given in Sir John's book unfortunately contain records from other pits also. The implements also require revision.

The following is a list and description of several which I have been successful in obtaining recently and which are now in the Sedgwick Museum. They suggest the occurrence in the gravel of artifacts of various dates from Chellean to early Mousterian. The Chellean implements require no further notice save that those obtained by me were all waterworn and may have probably been derived from earlier deposits. The Acheulean implements are on the whole less waterworn and some only slightly affected. Several flakes are of Mousterian type: two deserve special notice: one is of a buff colour with lighter patches, and measures 4½ in. by 3½ in. It has a facetted platform and the character of a Levallois flake. It is almost unworn, and is said to have been found near the base

of the pit. I have presented this to the Sedgwick Museum, Cambridge. The other, 5 in. by 2½ in., is a curved double scraper with plane platform, and the scraping surfaces are delicately trimmed. It is whitish with buff staining in places and also almost unworn. It is definitely stated to have been found in the upper part of the pit, about 4 feet from the surface. I may remark that the general assemblage of implements recalls those described by Professor Marr from the Traveller's Rest pit, Cambridge, though they are found far more abundantly, and are on the whole of higher quality, at Biddenham. I may mention that at the time of my visits the pit showed the following section :—

	ft.	in.
Top soil	2	0
Ferruginous gravel	4	0
Fine flinty gravel, light coloured, with sand partings and occasional false bedding	6	0
Coarse subangular gravel with boulders	6	0
	18	0

It is not my purpose in a paper of this kind to go into the question of the age of the Great Ouse gravels except to say that at Biddenham we have evidence of two deposits of different ages, an earlier and a later, as shown by the occurrence of implements of Acheulean and Mousterian type similar to those in the Traveller's Rest pit at Cambridge, and there is a striking similarity in their mode of occurrence at the two places.

B. Kingston, Cambs.

Kingston is one of the few places near Cambridge where gravel is found in association with Boulder Clay and it is therefore important to record sections here. (1) A ferruginous gravel containing pebbles is seen underlying what appears to be Boulder Clay in a road section near the Bourn brook, though it has been suggested that the clay is re-sorted Boulder Clay. (2) A well section seen in 1923 about 200 yards south of the church and at a height of about 130 feet above O.D., showed the following section :—

	ft.	in.
Clay soil	1	6
Grey boulder clay	5	9
Clayey gravel	1	8
Grey boulder clay with striated Chalk boulders	2	1

Gravel seen at one corner of well bottom, estimated 3 to 4 feet.

The interest of this section is twofold. I suggested that the gravel may be caught up in the Boulder Clay, in which Professor Marr concurs, but in any case it gives evidence of the existence of gravel older than the Boulder Clay of the area, and therefore accords with sections further south at Saffron Walden, Quendon, and elsewhere. Messrs. Rastall and Romanes (*Q.J.G.S.*, vol. lxv, 1909, p. 246) give evidence of the occurrence of two glaciations in this

district and the ploughing up of the products of earlier glaciation by the later one. Any gravels formed between the two periods of glaciation would also be ploughed up and incorporated in the later clay. The base of the Boulder Clay away from the Bourn brook is at a higher level than that at Kingston, suggesting sagging of the Boulder Clay into the valley, a feature noted by Professor Hughes in other parts of the Cam drainage area. This indicates the existence of the valley before the last boulder clay was deposited, and is opposed to the conclusion that the valley is entirely post-glacial and eroded through the Boulder Clay. I might here remark that the scraping up of older gravels by the Boulder Clay glaciation is not without some significance, and may help to throw light on some phenomena in other localities where the association of the Boulder Clay with other deposits is obscure; and perhaps the uneven bedding in the Traveller's Rest pit may be due to subsequent ice action at a later date, as suggested by Professor Marr (*Proc. Prehist. Soc. East Anglia*, vol. iii, p. 184).

In conclusion, my warmest thanks are due to Professor Marr for kindly describing the implements. This paper is written at his suggestion, and I shall be amply repaid if my efforts are of any service with reference to the question of the relationship of the Great Ouse and Cambridgeshire Pleistocene deposits.

Addendum.

I have more than once suggested that a fair test of the age of the Pleistocene gravels is derived from the percentage of Scandinavian rocks markedly characteristic of that area, and the absence of specifically British rocks, e.g. Lincolnshire Limestone, Millstone Grits, etc., and I may here remark that the Kingston sections show a fairly strong Scandinavian admixture. Dr. R. H. Rastall, to whom I referred the matter, was kind enough to report as follows: "In my opinion there is a fairly strong Scandinavian element in the Kingston assemblage: the rhomb-porphyry and nordmarkite are quite conclusive as to the actual occurrence of Scandinavian rocks there, although Scotch types are dominant."

For further reference *vide* Rastall and Romanes, on the Boulders of the Cambridge Drift, *Q.J.G.S.*, vol. lxv, 1909, pp. 246–64.

REVIEWS.

Évolution Géologique de la Terre et Ancienneté de l'Homme. By Alphonse Cels. pp. 627, 2nd edition, 8vo. Brussels, 1924.

THIS important-looking work may be regarded, like *The Glacial Nightmare and the Flood*, as a sad monument of wasted thought and misdirected endeavour. The writer is evidently a man of unusual ability with a fair knowledge of geological processes, but under the influence of preconceived notions which distort his intellectual vision.

The title of the work is a misnomer, for the history of the earth it sets forth is no evolution but a ceaseless succession of cycles reminding one of the Huttonian doctrine of a world without beginning and without end.

In tilting at windmills the author chooses for especial attack the received view of a successive appearance of faunas in time, which he regards not as based on observation but as a phantasm arising out of Darwin's theories. There are no such things as characteristic fossils, and it is impossible therefore to assign a date to a geological horizon. It seems strange that such a work should have reached a second edition, and we wonder where it finds readers.

Climatic Changes, their Nature and Causes. By Ellsworth Huntington and S. S. Visher. pp. xiii and 329. Newhaven: Yale University Press, and London: Humphrey Milford, 1922. Price 17*s.* 6*d.* net.

IN theory the Geological Society has always discouraged theory and encouraged the collection of facts. In practice it has not been very successful in distinguishing between them, and the "facts" of one generation are not the "facts" of the next; but it has generally succeeded in repressing the ideas that must have occurred to those who collected the facts, unless these ideas were particularly obvious. The present writer has long regretted the too rigid censorship, and has attributed to it the very sedate character of the *Quarterly Journal*. But the perusal of the volume under review has almost made him a convert to the Society's policy. That policy no doubt is based on a rather vague notion that if we accumulate sufficient facts the true theory will in time emerge without giving anyone the trouble to think it out. The American notion is that if we invent enough theories one of them is sure to be the true one, and the future will decide which. Huntington and Visher's book is typically American in method and it is no more enlivening than a Quarterly Journal.

It is surprising that it is not. Huntington's earlier work on changes of climate is very interesting. He showed that in Central and Western Asia there have been considerable fluctuations in rainfall during historic times, and these fluctuations seem to have

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It is surprising that it is not. Huntington's earlier work on changes of climate is very interesting. He showed that in Central and Western Asia there have been considerable fluctuations in rainfall during historic times, and these fluctuations seem to have

been periodic. He has since carried his investigations farther and into other regions, and the results obtained by himself and by other workers are summarized, somewhat incompletely, in the present volume. But the real purpose of the book is the development of the theory that these fluctuations are caused by variations in solar activity, as indicated by sunspots. It is a guess and not an unreasonable one, but it rests on a very slender basis of evidence. It has long been recognized that in tropical latitudes there are slight variations in temperature and storminess associated with the eleven-year sunspot period, though in temperate latitudes the connexion is very obscure. There is some weak historical evidence that during the "Climatic Stress of the Fourteenth Century"—to quote the title of the sixth chapter—the sunspots were at times exceptionally striking. In addition to the well-known eleven-year sunspot period there may be periods of a few hundred years with greater maxima, and these may produce a greater effect upon the climate and thus account for the climatic variations of historic times. The authors go farther. There may be periods of several thousand years with still greater maxima, and a still greater effect upon climate, and if other conditions are favourable a glacial period may be produced.

It is a guess that these longer periods exist. If they do, it is a further guess that the sunspot variations due to them are so large as to mask the effect of the eleven-year period. If they are, it is another guess that their effect upon climate is great compared with the very small effect produced by the considerable sunspot variations of the eleven-year period. The reasoning may be analysed thus:—A is probably true: if A is true, probably B is true; if B is true, probably C is true; and from this sequence the authors appear to think themselves justified in concluding that C is probably true. A very slight acquaintance with the theory of probabilities is sufficient to show that unless the probability at each step is decidedly high, the probability that the conclusion is correct is decidedly low, considerably lower than the probability that A is true. Without any acquaintance with the theory of probabilities the man in the street instinctively, and justly, distrusts reasoning of this kind—unless it is a party matter and the argument is that of his own party.

In their long and involved attempt to show that in favourable circumstances greatly increased solar activity will produce glacial conditions the authors become really tedious, and the type of reasoning already referred to is used with the greatest freedom. The plain man may be forgiven for thinking that if our present knowledge of the eleven-year sunspot period does not enable the Meteorological Office to say whether the summer is likely to be warm or cold, it is extremely improbable that Huntington and Visher can tell us what the effect of the longer periods will be, if there are such longer periods.

It is to be regretted that so many American writers do not realize how rapidly a sequence of deductions diminishes in strength when each step is only probable. If they did their writings might lose in volume and tedium, but they would gain in force and interest.

P. L.

Structural Relations of the Bushveld Igneous Complex, Transvaal. By R. A. Daly and G. A. F. Molengraaff. Journal of Geology, vol. xxxii, No. 1, 1924, pp. 1–35.

THE study of any igneous body with a floor or a roof or, best of all, with both, is obviously of the greatest importance to petrogenic theory. When a floored igneous body (before this paper, one could have added roofed, too) reaches the colossal size of the Bushveld sheet and shows, besides, such an extreme variation, then repeated investigation, especially by new workers able to bring fresh ideas to bear upon the problems awaiting solution, becomes particularly desirable.

Professor Daly organized a Shaler Memorial Expedition from Harvard University, consisting of himself, Professor Palache, Professor Molengraaff, and Dr. F. E. Wright; the South African geologists, Messrs. Hall, Rogers, du Toit, and Wagner, cordially co-operated with them. General agreement seems to have been reached among hosts and visitors alike, and this paper, though under the names of but two of the Expedition, represents the views of the whole party.

The chief question dealt with in this, the first, one assumes, of the reports, concerns the relation of the Bushveld Complex to the overlying Waterberg System. The history of opinion on this question is summarized. The Waterberg System of the Geological Survey of South Africa has two members—an upper sedimentary mainly arenaceous and conglomeratic one, separated by an unconformity from a lower mainly acid volcanic one. Hitherto, it has been considered that the Red Granite, the youngest member of the Bushveld Complex, was intrusive into the Upper Waterberg. The Authors examined the evidence at the two localities, Balmoral and Gatkop, where this intrusive relation had been considered demonstrated, and came to the conclusion that the Upper Waterberg rests, with a marked unconformity, on the rocks of the Complex.

This conclusion is followed by certain interpretations of the utmost interest. The authors consider the Lower Waterberg to represent the volcanic top, open to the sky, of the Bushveld Complex; the felsite flows and associated pyroclastics are believed to pass downwards into granophyre; it is known that the granophyre passes downwards into norite. Thus the igneous body over large areas had no sedimentary roof at all, and the felsite granophyre-norite assemblage may be regarded as a colossal differentiated lava-flow. The extrusion of this is suggested to be due to the foundering of the roof of the great sheet, following the differentiation

of an injected mass. Afterwards occurred the intrusion of the Red Granite in typical plutonic fashion.

The larger part of this paper deals with the relation of the Complex to the Waterberg System, and is on an entirely different footing from certain of the conclusions which are somewhat dogmatically stated at the end. How far the field evidence substantiates the unity of the felsite-granophyre-norite assemblage is not indicated, nor is Kynaston's suggestion—that the Lower Waterberg represents the early volcanic phase afterwards cut plutonically by the granophyre-norite sheet—sufficiently discussed. Probably future reports will fill in these and other gaps in the argument.

The authors' interpretation of the stupendous Bushveld Complex as an extrusion by deroofing leads one to entertain very lively expectations as to the nature of future reports of the Expedition. Foundering of a roof on such a scale suggests, in some position, wholesale assimilation. Indeed, it seems feasible that de-roofing extrusion may be due primarily to the piecemeal eating away of the roof, rather than to simple foundering. All students of igneous geology, and especially those concerned with the granite-norite assemblage, will look forward to forthcoming reports of this Expedition.

H. H. R.

OUTLINES OF PALÆONTOLOGY. By H. H. SWINNERTON. pp. i–xii, 1–420, 368 figures. London: E. Arnold & Co., 1923. Price 30*s*.

THIS work deals with Palæontology from an evolutionary point of view. Its scope is indicated in the Preface by the statement that "most problems are discussed in terms of organs and structures rather than organisms and species". This morphogenetic rather than phylogenetic treatment is probably a case of necessity rather than choice, for although much has been written on phylogeny it is remarkable how little is actually known and how seldom any two specialists are in agreement. The trend of evolution in a single organ or structure is, however, a much less complex subject than the history of a race.

The author covers a wide field, ranging from Foraminifera to Man—a range which only a teacher of long experience could venture to attempt with any hope of success. The treatment of the various groups appears to us well balanced, but is obviously determined by the published information available, so that some groups on which much has been written (e.g. Cephalopods) are dealt with at greater length than others on which comparatively little has been done from an evolutionary standpoint (e.g. Gasteropods). Specialists will no doubt find statements with which they do not agree; but to arouse the interest and enthusiasm of students, as we think the author will certainly do, seems to us more important in a work of this kind than absolute accuracy in details. Professor Swinnerton

states that "the work originated in the class room rather than the laboratory", from which we are led to infer that it is to be regarded mainly as an exposition of the work of others. His exposition is clear and logical, and should be easily followed by students who have some elementary knowledge of Palæontology; but in some places a rather more critical treatment could be desired. For example, the Tabulate Corals are referred to the Alcyonaria without question, although much might have been said for another view of their relationship. We note, however, that the author finds in the Graptolites evidence of their affinity to the Hydromedusæ.

The book is abundantly illustrated by figures which are intended to explain structures rather than to show generic characters. In the explanations of the figures there are several misprints which may cause students some trouble. The shortness of the Bibliography and the statement that "usually only the more recent references are given" disarms criticism. We regret that the price of the book will place it beyond the reach of many students, and hope that the publishers will be able to remedy this when a new edition or a reprint is called for.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

March 18.—Dr. A. E. H. Tutton, F.R.S., past-president, in the chair.

Dr. L. J. Spencer: Allopalladium from British Guiana. Three small grains with the appearance of native platinum, from the gold and diamond washings on the Potaro River, answered to microchemical tests for palladium; but the material is brittle and consists of a granular crystalline aggregate showing cleavages.

W. Campbell Smith, with analysis by Dr. G. T. Prior: On compact chlorite from Bernstein, Burgenland, Austria. Specimens of compact dark-green stone provided by The Styrian Jade Company prove to be chlorite intermediate in composition between pennine and clinochlore of Tschermak's classification of the chlorites: "Precious Serpentine" from the same locality was analysed and identified as chlorite by Wartha in 1884.

H. C. G. Vincent: Chemical analyses of microgranite from Dufton, Westmorland, and of mica from Burma. Analysis of the microgranite with porphyritic mica from Dufton showed an excess of soda over potash; the mica from Burma had the composition of a phlogopite like that of Burgess, Ontario.

CORRESPONDENCE.

AN ANTHOLOGY OF SCIENTIFIC VERSE.

SIR,—During the past five years I have been collecting verse whose subject matter relates to the sciences, with the intention of publishing at some future date an anthology of this poetry. It has occurred to me that perhaps the readers of the GEOLOGICAL MAGAZINE would be willing to help me in collecting together this sort of verse in order to make the anthology—the first of its kind—of the greatest value to scientists, and to this end I am writing you to ask you to insert my appeal for assistance and co-operation in gathering the stray specimens of poetry of this character. Verse of all forms and moods, provided that the subject matter relates to the sciences, is acceptable and desired. All contributions sent to C. E. Ruby, Massachusetts Inst. of Technology, Cambridge, Mass., U.S.A., will be duly acknowledged.

C. E. RUBY.

27th May, 1924.

EOCENE CYCLES OF SEDIMENTATION.

SIR,—In view of the fact that I have already apologized for a possible lack of clarity in my "Introduction to Stratigraphy", there is little that I can say in reply to the letter of Mr. Wells and Mr. Wooldridge in your April number, except to promise that the necessary clarifying phrases will be inserted in future editions. Whilst thanking them for their generous remarks on my work, it is perhaps a little unkind of Messrs. Wells and Wooldridge again to quote isolated sentences from my "Stratigraphy". Far be it from me to retaliate, but it is of interest to note that in December my friends said, "As regards the Wealden anticline, it would be foolish to deny that the early stages of its growth influenced Eocene sedimentation." Now (April) they say, "We have yet to see that the Weald was being uplifted at all during Eocene times." Adherence to the former statement would leave us in almost total agreement.

L. DUDLEY STAMP.

UNIVERSITY OF RANGOON.
9th May, 1924.

FIG. 1

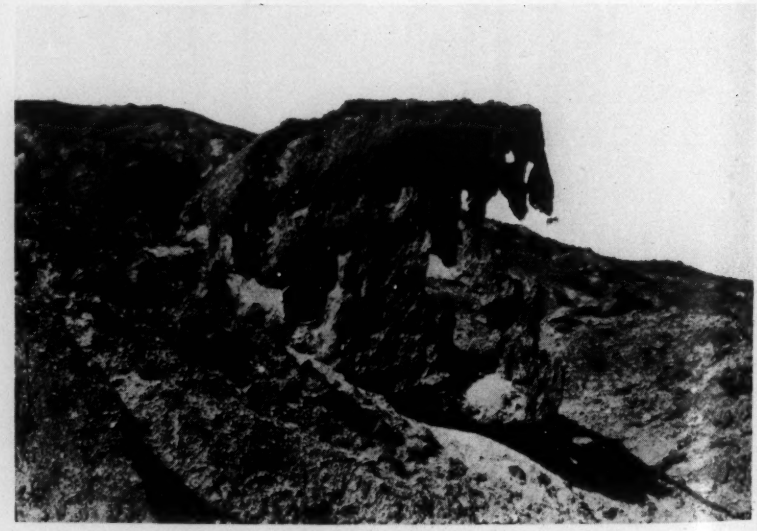

FIG. 2

HOLLOW BLOCKS OF LIMESTONE, CABO BLANCO, PERU.